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# QUARTERLY PROGRESS REPORT

## DIVISION 6 — DIGITAL COMPUTER (U)

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15 SEPTEMBER 1957

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LINCOLN LABORATORY

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HEADQUARTERS
NORTH AMERICAN AEROSPACE DEFENSE COMMAND
PETERSON AIR FORCE BASE, COLORADO 80914-5001

REPLY TO ATTN OF J30S

26 NOV 1984

SUBJECT Classification Review "Quarterly Progress Reports"

TO ALFL (Lincoln Laboratory)

1. In response to ALFL letter, 28 Nov 83, the (11) confidential documents titled "Quarterly Progress Reports - Division 6 - Digital Computer" and dated 15 Jun 1954 through 15 Dec 1958 have been reviewed. Recommend the documents be declassified in whole since the sage system computer no longer exists and information contained in the documents no longer has an effect on national security.

2. To officially declassify these, documents, the 416L Security Classification Guide OPR, which is at HQ Sacramento Air Logistic Center, McClellan AFB, CA (MMCM), must be contacted with the recommendation to declassify.

JOHN E. MOORS, LCOL, CF
Ch, At Sensors Division

Memo for Record 14 Dec 84

Talked, by phone, with Ed Smalden, Sacramento ALC/MMCM, McClellan AFB, CA. Based on the recommendation in this letter he considers these documents declassified.

THOMAS J. ALPERT, MAJOR, USAF
CHIEF, ESD LINCOLN LABORATORY PROJECT OFC

AFL

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ELECTRONIC SYSTEMS DIVISION (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

REPLY TO ATTN OF: ALFL (Lincoln Laboratory) 17 Dec 84

SUBJECT: Declassification of Lincoln Laboratory Documents

TO: Mr. M. Wesley/A-109
Security Office
Lincoln Laboratory

1. Reference your letter of 17 Nov 1983 requesting declaassification and public release of MIT Lincoln Laboratory Quarterly Progress Reports issued between June 1952 and December 1958 (see atch 1).

The first major hurdle of this process has been cleared. Attachment 2 authorizes the declassification of the following documents:

"Quarterly Progress Reports - Division 6 - Digital Computer"

15 Jun 1954 (C)-(LL # 1, C315172C)
15 Sep 1954 (C) (LL # 1, C315189C)
15 Sep 1956 (C) (LL # 1, C315208C)
15 Mar 1957 (C) (LL # 1, C315206C)
15 Jun 1957 (C) (LL # 1, C315253C)
15 Sep 1957 (C) (LL # 1, C315254C) #1716
15 Dec 1957 (C) (LL # 1, C315255C)
15 Mar 1958 (C) (LL # 1, C315256C)
15 Jun 1958 (C) (LL # 1, C315257C)
15 Sep 1958 (C) (LL # 1, C315258C)
15 Dec 1958 (C) (LL # 1, C315313C)

The next major hurdle is obtaining public release. This will be done through ESD Public Affairs (Mr. John O'Brien).

ORIGINAL SIGNED BY

THOMAS J. ALPERT, Major, USAF
Chief, ESD Lincoln Laboratory Project Ofc

2 Atch
1. Lincoln Laboratory Ltr, 17 Nov 1983
2. NORAD Ltr, 26 Nov 84

Cy to: D. Murphy/B-107 w/atch
W. Hill/L-339 w/atch

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# QUARTERLY PROGRESS REPORT

## DIVISION 6 – DIGITAL COMPUTER (U)

#1716

15 SEPTEMBER 1957

ISSUED 12 MAY 1958

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY LEXINGTON, MASSACHUSETTS

## DIVISION 6 HEADQUARTERS

### DIVISION HEAD

R. R. Everett

### ASSOCIATE DIVISION HEAD

N. H. Taylor

### ASSISTANT DIVISION HEADS

S. H. Dodd
J. F. Jacobs

### STAFF ASSISTANTS

C. W. Farr
T. R. Parkins
J. C. Proctor

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## DIVISION 6 SUMMARY

During the period June, July, and August, adaptation of direction center active (DCA) programs continued at several direction centers. In ESS, the Experimental SAGE Sector, successful tests were run with Package D (in which weapons direction functions were added to the air surveillance portion of the DCA program); tests of the semiautomatic height finding function were conducted; and ground-to-air voice radio and data link communications were integrated. Mode II (adjacent sector disabled) capability was detailed and several new features of manned interceptor capability for 1959 SAGE were proposed. The 1959 SAGE revision will consist of a series of improvements based on availability schedules of the new features to be added.

Assembly of the TX-2 experimental computer is expected to be complete by late spring. Progress in the studies of magnetic materials is now being reported in Lincoln Laboratory Quarterly Progress Report, Solid State Research, Groups 24, 35, 37, 63, and 310 (Unclassified).

Air defense computer programs were adapted for direction centers at McGuire, Stewart, Syracuse, and Fort Lee. At McGuire, Package D of the direction center active (DCA) program was 95% verified for delivery to Western Electric Co. in mid-September. At Stewart, tests of the initial version of the DCA program found no major discrepancies.

In the Experimental SAGE Sector (ESS) Package D was tested and found to be fundamentally operational. For the first time in ESS intercept directors vectored F-86 interceptors into successful final tactics against B-47 and B-52 strike aircraft. By the end of the quarter it was concluded that the air defense functions of Package D are capable of meeting design specifications under normal or heavy load conditions.

Seven tests of the semiautomatic height finding function were carried out using Montauk, South Truro, and Bath radar sites. Ground-to-air voice radio and data link communications were integrated into the system and furnished with appropriate checkout routines.

Details of Mode II (adjacent sector disabled) capability were worked out in cooperation with Air Defense Command. In taking over a disabled sector, a normal sector in Mode II will lose some defense capability in the form of capacity per unit area, but the character of the defense will not change.

The planned implementation of the 1959 SAGE revision will be a series of progressive improvements taking place over a period of about two years. The schedule for changes to the system will be based upon established or estimated availability of the new features to be integrated.

Seven major new features of manned interceptor capability were proposed for the 1959 SAGE revision. An ADC employment plan for time-division data link was released on 15 June. DCA program revisions necessary for frequency-division data link were published. A study of the DCA program operating time indicated that frame time (the total of subprogram operating times and control time – nominally 15.7 seconds) will be adequate for the data processing requirements of the initial SAGE system.



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Two 4096 register (64 × 64) transistor driven core memories are being assembled – one with a 38 bit word length for the TX-2 and one with a 20 bit word length for the TX-0 experimental computers. Assembly of the TX-2 is proceeding satisfactorily and it is expected to be in limited operation late next spring.

Group 63 studies of magnetic materials for the period 1 July – 30 September have been included in Lincoln Laboratory QPR Solid State Research, Groups 24, 35, 37, 63, and 310 (Unclassified) 1 November 1957. A summary of these studies is included in as an appendix to the Group 63 report.

R.R. Everett
Division Head

N.H. Taylor
Associate Division Head

J.F. Jacobs
Assistant Division Head

14 April 1958



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TECHNICAL INFORMATION RELEASES

1 June 1957 – 31 August 1957

| TIR | Release Date | Material Released |
|---|---|---|
| 1-209 | 21 June 1957 | SAGE Ground-to-Air Voice Communications: Parallel Operation of VHF-UHF Emergency and AICC. |
| 1-210 | 26 June 1957 | Recommendation for Mark X Operation in SAGE. |
| 1-211 | 30 July 1957 | Required Modifications of 1300 to 750 Converter. |
| 1-212 | 8 August 1957 | Orientation of Gap Filler Radars by Solar Radiation Procedures. |



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SYSTEM DESIGN

GROUP 61

ISRAEL, D. R., *Leader*

ANDERSON, H. E.
CLEVELAND, W.
DOMINITZ, J.
EARNEST, L. D.
GARTH, F. M.
GLATFELTER, G.
GOLDBERG, S.
GOODMAN, H.
HAUSER, S. J.
JEFFERY, L. R.
LADD, D. W.
LEE, W.
LITSIOS, S.
SHAY, J. W.
SHOOLMAN, A. R.
SINESI, P. N.
WOLF, E. W.

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# I. SYSTEM DESIGN
## GROUP 61

### A. SUMMARY

Group 61 continued the study of problems associated with the integration of new weapons into the SAGE system, and prepared proposals and specifications for certain phases of the integration: Currently under study are manned interceptors, the BOMARC IM99A, time-division data link, the simulation of weapons performance and SAGE functions, and the improvement of weapons direction capability.

Seven major new features of manned interceptor capability in 1959 SAGE were proposed. Specifications were written for preliminary flight tests of the F-102, and one test was conducted in the Cape Cod System.

The writing of specifications for the SAGE non-real-time (SNORT) simulation continued: A draft of the track-while-scan (TWS) and weapons guidance and tracking (WGT) portions were prepared and verified with Boeing, which is writing the guidance and missile model programs for the BOMARC missile. Planning continued for tests using another BOMARC simulation, BISEPS II, at Kingston beginning in November, 1957; Group 61 will design and conduct the tests and interpret the resulting data. Specifications for the basic operating program of the automatic target-battery evaluation (ATABE) program were completed.

Several questions relating to the integration of time-division data link were defined and/or resolved in an ADC employment plan released on 15 June to which Group 61 made substantial contribution. Revisions to the SAGE DCA program necessary for frequency-division data link were published in a Lincoln memorandum (6M-4483). A study group has proposed that several weapons assignment and direction functions, such as selection of weapons, be made automatic.

D. R. Israel

### B. MANNED INTERCEPTORS

Group 61 has published a proposal for manned interceptor capability in 1959 SAGE.* It describes the system requirements to integrate the following aircraft types which are expected to be in ADC operational use at that time: F-86D and L; F-89D, H, and J; F-94C; F-101B; F-104A; and F-106A. It was prepared with the assistance of the 4620th Air Defense Wing and representatives of the weapons contractors.

The proposal is an extension of current operational and mathematical specifications for intercept direction, and particularly of those described in 6M-4470, "Detailed Specifications for Manned Interceptor Section of 6M-4485," which was published on 12 July. Added capabilities include profile selection, fuel monitoring, modified close control, snake attacks, acceleration to combat speed, automatic tactic selection, and improved computational techniques.

It is expected that the system capabilities proposed in the memorandum can be achieved without major equipment changes – either to SAGE or to the interceptor aircraft – beyond those

* 6M-4490: "Proposed Manned Interceptor Capability for SAGE," 30 July 1957.



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presently required by time-division data link or SIF integration in SAGE. Equipment changes which could provide additional capability are described in an appendix to the memorandum. The details of the proposal are now being written and will be issued as M-notes consecutively numbered from 6M-4490.

### 1. Preliminary Flight Tests of the F-102

Specifications were completed for a series of flight tests to precede full-scale testing of F-102's in ESS. The first flight test was conducted in August using the Cape Cod System. Two F-102A's were vectored against two B-47's flying at 37,000 feet: two good passes were made in spite of equipment difficulties. The primary objective of the flight tests is to give pilots experience in flying F-102A intercept missions. In cooperation with Group 67, Group 61 began preparation of specifications for a manned interceptor test facility in ESS.

L. R. Jeffery

## C. SIMULATION STUDIES

### 1. SNORT

The SAGE non-real-time (SNORT) simulation is to be a family of computer programs which will simulate SAGE automatic tracking and guidance functions. BOMARC will be the first weapon simulated, with manned interceptors and other missiles to follow. SNORT is written

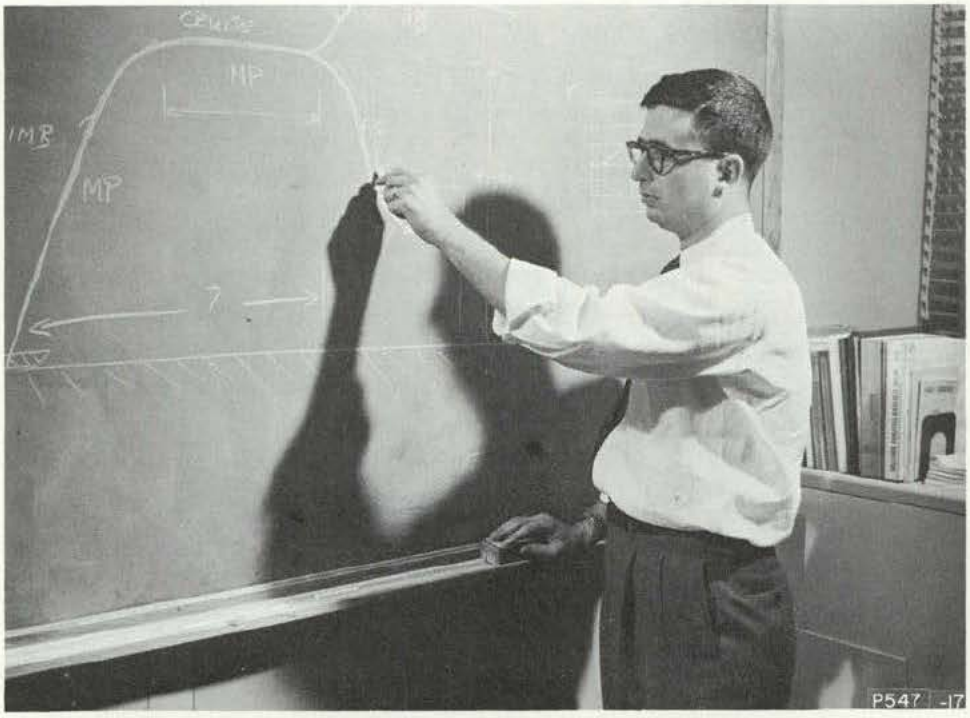


Fig. 61-1. Discussion leader outlines interceptor problems to guide computer programmers.

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for an IBM-704 computer and will have a capacity of 150 tracks and 75 simultaneous interceptions. SNORT logic is divided into two packages: track-while-scan (TWS) and weapons guidance and tracking (WGT). TWS will consist of a target tracking program operating on target radar data furnished by the simulated-data-generation tape, and will include data recording and reduction programs. WGT will consist of weapons assignment, interceptor simulation, interceptor data generation, interceptor tracking, and interceptor guidance, as well as associated data recording and reduction programs. Because SNORT is made up of these clearly separable component programs, it has the same versatility as the SAGE DCA program; e.g., the WGT-BOMARC subprogram may be interchanged with a manned interceptor or other missile WGT program.

In June the program specifications for the TWS and WGT portions of SNORT were explained to representatives of the Boeing Airplane Company and discussed with respect to the guidance and missile model programs being written by them. Table design criteria were subsequently prepared and the TWS package was given to Group 67 for writing.

Boeing will be responsible for the mathematical specifications for the missile model, missile guidance, and missile assignment programs of WGT, and they will code these programs under Lincoln supervision. Lincoln is responsible for the SIF beacon data generation and missile tracking programs. Missile tracking will be performed as specified in 6M-4892, "Missile Tracking in the SAGE System for Initial BOMARC Tactical Integration." Programs to reduce the data from the simulation for analysis will be written by IBM.

## 2. BOSCO/ BISEPS I/ BISEPS II

BOSCO (BOMARC/SAGE Compatibility), the initial computer program for the integration of BOMARC into SAGE is being written by IBM, and will be operated on the AN/FSQ-7 (XD-2) computer at Kingston for test firings at Patrick Air Force Base, Florida. BISEPS I (BOMARC-Interceptor SAGE Experimental Computer Program Simulation) is a non-real-time program written by IBM for XD-2 and will be used by them to check out flight test procedures and the adequacy of the BOSCO program before the first set of live tests with the XIM-99A from Patrick Air Force Base. BISEPS II is a real-time simulation written for XD-2 by IBM with the assistance of Group 61 for tests which will be conducted and evaluated by Group 61. It uses the basic tracking and guidance programs of BOSCO, modified to operate in a simulated environment incorporating the principal features of the planned tactical integration of BOMARC with SAGE. The basic components of BISEPS II are:

(a) BOSCO tracking,

(b) BOMARC guidance as specified in 6M-4893-1, *

(c) Weapons assignment, with facility for precommitment, recommitment, and multiple firing,

(d) Missile simulator and beacon data generator,

(e) Data recording and data reduction subroutines.

* 6M-4893-1, "Guidance Program Changes to the SAGE System for Initial BOMARC Tactical Integration," 8 August 1957.



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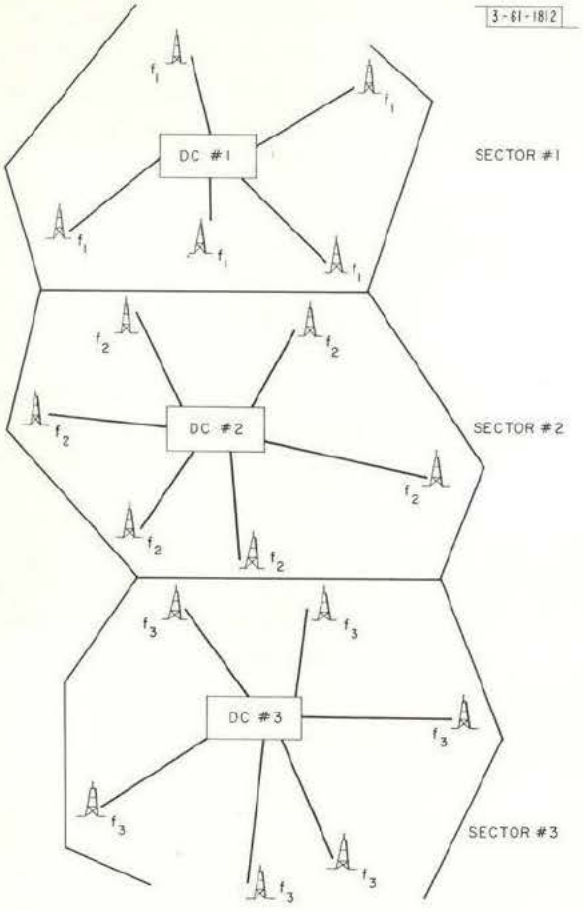


Fig. 61-2. Mode I (normal) data link network.

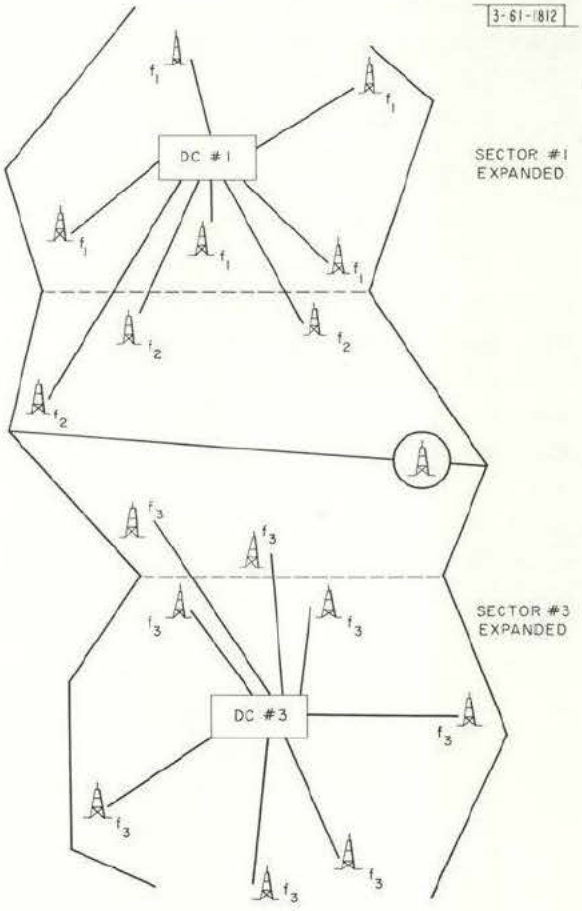


Fig. 61-3. Mode II (emergency) data link network DC #2 has been disabled.

BISEPS I and II will be checked out in the period September 1957 to January 1958. Initial testing using BISEPS II will begin on 1 February 1958. Group 61 will design and conduct 50 one-hour tests to be conducted in real-time using the XD-2 computer and three situation display consoles manned by a weapons director, an intercept director, and a test supervisor. Each one-hour test will handle an average of 40 target track interceptions. Data collected from the tests will be interpreted by Group 61.

A.R. Shoolman
E.W. Wolf

## D. DATA LINK

### 1. TDDL Employment Plan

Group 61, representing Lincoln, contributed to a 5-day ADC meeting in June at RCA, Camden, New Jersey at which ADC drew up an employment plan for time-division data link (TDDL). Present at the meeting were representatives of various weapons contractors and USAF, ARDC, RAND, RCA (which is making the airborne equipment), IBM (which is making the output section), and GE (which is concerned with the GPA-37 ground environment).

One of the more troublesome aspects of the employment of TDDL is its simultaneous use with frequency-division data link (FDDL) during the period of conversion from the latter to the former. The employment plan describes the effect of this simultaneous operation on the airborne and ground equipments. SAGE direction center equipment and computer programs will be modified to communicate with manned interceptors and BOMARC's equipped with either TD or FD equipment. The AN/FSQ-7 will require the addition of a TDDL output section which will serve for both manned interceptors and BOMARC, and changes to the computer program to provide the following:

(a) Selection of the individual transmitter which will be received best by the interceptor or missile,

(b) The composing and sequencing of the messages,

(c) Mode II (emergency) operation,

(d) Choice of data link type (FD or TD).

The resolution of a second problem, SAGE netting in Mode II operation, is described. Mode II operation is put into effect when a direction center (DC) is disabled and DC's in adjacent sectors expand their control area to include the disabled sector. Fig. 61-2 shows three adjacent sectors in normal operation (Mode I): each direction center is connected to a number of data link transmitters tuned to frequencies ($f_1$, $f_2$, and $f_3$) which are consistent within a sector.

Fig. 61-3 shows the network in Mode II operation. DC No. 2 has been disabled. DC's Nos. 1 and 3 expand their control to the transmitters in Sector 2 as shown. The upper three transmitters of the disabled sector maintain their frequency, while the lower two return to $f_3$ in order to prevent interference with the upper three. The circled transmitter illustrates the extreme case in which it would become the ninth site in an expanded sector; and, because the present computer output message format contains a maximum of eight site addresses, this ninth site is not in communication with the DC.

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### 2. SAGE Program Revisions for FDDL

The USAF-ADC document "Operational Plans for Frequency-Division Data Link" dated 14 May 1957 has been reviewed and the changes to the SAGE program necessary to make it compatible with the operational plan have been published in 6M-4483, "SAGE Program Revisions for Frequency-Division Data Link" dated 31 July 1957. The changes are as follows:

(a) Send the target altitude and command speed to all interceptor types,

(b) Send command altitude as well as target altitude to the F-106A and the F-104A* interceptors.

Two additional changes proposed by Group 311 are:

(a) Introduce a new test message and a new sequence for transmitting it,

(b) Make up data link messages for all computer-vectored interceptors even if some have voice control only.

H. E. Anderson
L. R. Jeffery

## E. ANTIAIRCRAFT OPERATION: ATABE

Group 61 is currently writing specifications for the automatic target-battery evaluation (ATABE) computer program, the basic operating program specifications for which were completed during the quarter. The ATABE program will evaluate the total threat to a Missile Master defense area, rate the threat of individual tracks, and select particular AA batteries to engage specified tracks. The threat criteria include position, heading, speed, flight size, number of other weapons (BOMARC or manned interceptors) assigned, and possible manual interventions. The criteria for selecting a particular battery include time-to-first-intercept, potential length of engagement, and warhead availability. The program will also process status messages from the batteries and prepare commands to be transmitted to the batteries via the Missile Master. Plans are now being drawn up for a non-real-time evaluation of the ATABE program.

Group 61 is furnishing technical support to USAF Hq. at Colorado Springs for the broad planning for the integration testing of the SAGE Missile Master system.

G. Glatfelter
W. Lee
J. W. Shay

## F. WEAPONS DIRECTION STUDY

A three-months study by Group 61 and the 4620th ADW has resulted in the publication of 6M-4448, "Weapons Direction Study," dated 24 June 1957. The memorandum proposes that several of the present weapons assignment and direction functions be made automatic. The

* Command altitude is not included in "Operational Plans for Frequency-Division Data Link" as a requirement for the F-104A. It is included, however, in the memorandum "Programming for Frequency-Division Data Link" 29 May 1957 from the Director, Technical Functions, 4620th ADW.



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senior weapons director would be provided with additional control switches and be able to operate in any one of three options: an SWD (senior weapons director) option, a WD (weapons director) option, or an automatic option. Functions common to all three options are as follows:

(a) Targets would automatically be assigned to WD teams and intercept directors (IND). Assignment to WD's will be according to target location; assignment to IND's will be such as to distribute the load equally.

(b) The SWD would be able to indicate the purpose of an assignment as either ENGAGE or IDENTIFY. He will be able to control the use of weapons with the COMMITMENT RATIO and BOMARC and/or NUCLEAR WARHEAD AUTHORIZATION actions.

(c) Scramble messages would be sent over an automatic scramble circuit to the airbases.

(d) The IND would have the ability to SPLIT and RECOMMIT command interceptors.

The SWD option would be used when the SWD is personally capable of handling each of the incoming targets. The SWD would commit weapons by assigning a target to a WD, who would then get an automatic weapons assignment display to use for the required weapons.

In a WD option an automatic weapons assignment display, using a target priority scheme, is presented to the WD's. They commit weapons by switch action.

The automatic option assigns targets to WD's by the same priority scheme as above; however, no weapons assignment display appears and no action is required for the WD's for weapons commitment. The best choice of weapons is computed and automatically scrambled on the target in order of priority.

S. Litsios



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ESS INSTALLATION

GROUP 62

O'BRIEN, J. A., *Leader*

CANTY, W. J., *Associate Leader*

ARONSON, I.
BARRETT, B. W.
BUNTING, J. H.
CALLAHAN, R. J.
CARTER, C. J.
COFFIN, S. T.
CRANE, J. D., JR.
DURGIN, F. R.
FALLOWS, R. S.
FLANAGAN, M. J.
GERHARDT, R. H.
GINSBURG, S. B.
HINGSTON, A.
IRISH, F. E.
JAHN, R. C.
MALOUIN, J.
PADDOCK, R. B.
SANDERS, C.
SANDY, G. F.
SANDY, T. J.
SWEENEY, F. J.
WERLIN, A. M.

# II. ESS INSTALLATION
## GROUP 62

## A. SUMMARY

A decision was made to incorporate Bell data service in the time-division output section in ESS, and NET&T was directed to make the installation. IBM has agreed to install the 65,000-register core memory in AN/FSQ-7 (XD-1) with a minimum of interruption in computer operation. The installation will be made in five steps and will be completed by October 1958.

Seven tests of the semiautomatic height finding function were carried out using Montauk, South Truro, and Bath. Emphasis was placed on the Montauk height finders which turned in satisfactory results in four of the seven tests. A comprehensive routine for height finders was incorporated in the equipment checkout (ECO) program. Ground-to-air voice radio and data link communications were integrated into the system and furnished with appropriate checkout routines.

Several devices were designed and made to improve the effectiveness and facilitate the testing of subsystems and equipment. Typical of these is an LRI simulator, which generates simulated long-range radar inputs data for testing input-output equipment.

J. A. O'Brien
W. J. Canty
R. S. Fallows

## B. COORDINATION OF ESS MAINTENANCE

One section of Group 62 acts as a common tie point for all equipment activities in ESS. It is primarily a service organization whose function is to provide ESS users with a system that has been checked out and has the desired program operating in the computer. Its activities depend upon checkout programs, special test equipment, a reliable method of locating equipment malfunctions, and the facilities and cooperation of all equipment and user groups. Problems of larger scope may be taken under long term study in cooperation with IBM.

### 1. Bell Data Service

On 22 July, Lincoln informed the New England Telephone & Telegraph Co. of its decision to incorporate Bell data service in the time-division output section in ESS. The ESS output section will thus be the same as those in SAGE production sites: it will feed the Bell DDT (digital data transmitter) with three signals – one carrying data, one a synchronization pulse, and one a timing signal. A previously mentioned problem of recording this output for test purposes remains to be solved.

### 2. 65,000-Register Core Memory

Agreement has been reached between Lincoln and IBM on a plan to install the 65,000-register (256 × 256) core memory in AN/FSQ-7 (XD-1) with a minimum of interruption in computer operation. The installation will be made in five steps between October 1957 and October 1958. A number of new instructions and modifications to the present program will be required, some of

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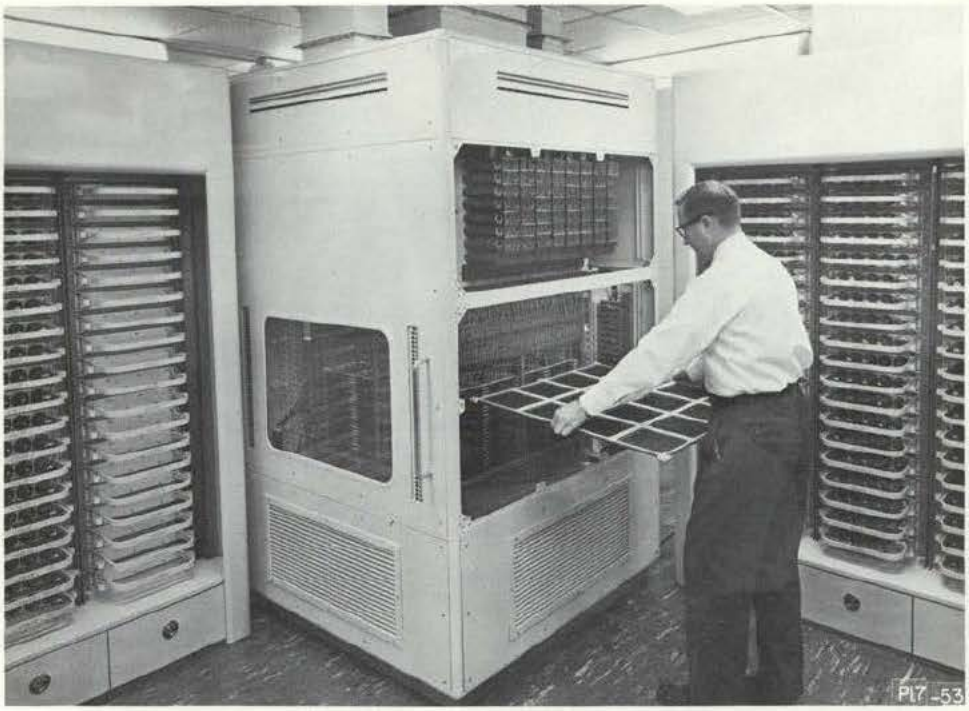


Fig. 62-1. The prototype 65,000-register magnetic core memory installed in TX-2. The large plane shown removed from the stack is made up of 16 units, each a 64 × 64 matrix of ferrite cores. The SAGE version will have a 32-bit word length as do the present operational core memories, but will possess 16 times the storage capacity.

them to adapt the new memory to the DCA program, others to aid in logical decision functions and reducing the operating time of the master program. The memory itself will be installed in the last step.

### 3. AN/FSQ-7 (XD-1) Reliability

AN/FSQ-7 (XD-1) reliability averaged over the quarterly period was as follows:

| | |
|---|---|
| Total Computer Hours | 953.64 |
| Per cent Good Time | 92.7 |
| Mean Free Time Between Failures (Hours) | 8.77 |
| Average Lost Time per Interrupting Incident (Hours) | .63 |

All figures apply to the computer system less displays and manual input keyboards.

I. Aronson
J.H. Bunting
C.J. Carter
M.J. Flanagan
F.E. Irish

## C. SUBSYSTEMS INTEGRATION AND MAINTENANCE PROCEDURES

Another section of Group 62 supports ESS coordination by designing programs and techniques that will permit checkout of remote equipment from the direction center in a series of subsystem



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tests. In addition, it prepares checkout programs and maintenance routines for new equipment incorporated into the direction center.

### 1. Radar Inputs Test

Seven radar inputs tests were conducted using height finders at Montauk, South Truro, and Bath. The tests examined the semiautomatic mode of the height finding function by a closed loop of computer generated requests and site replies: the radar itself was not tested, only the input-output equipment at the direction center and at the site. Particular emphasis was placed on the Montauk height finders since this site is being prepared for integration into ESS. Four of the seven tests indicated satisfactory performance of this subsystem. The South Truro height finders participated in five of the tests, averaging 95% correct replies in four of them. Bath participated in only one test with fair results.

One radar inputs test used a single-track tracking program with the Mark X search radar and height finders at South Truro and Bath only. Although an improvement in overlap tracking

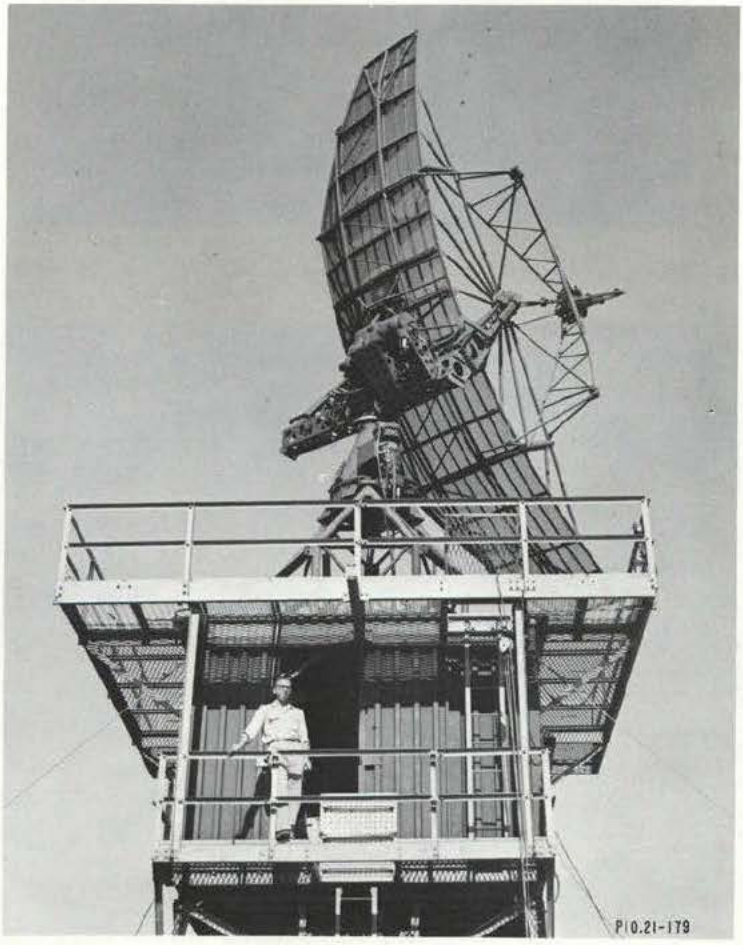


Fig. 62-2. Height finder radar antenna at South Truro, Massachusetts.



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GROUP 62

Fig. 62-3. Checkout of Ampex FR-100 tape recorder and associated electronics before operational use in ESS.

Fig. 62-4. Example of typical Charactron display in which brightness decreases with length of vector.

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accuracy was observed, height finder data has not been sufficiently reliable to evaluate the subsystem. Tests are being continued in an attempt to isolate error sources.

### 2. Height Finder Checkout Routine

A new program has been added to the equipment checkout routine which displays all radar inputs, transmits known ground-to-air data link test messages, transmits a stream of dummy height request messages to the height stations for their DDR (digital data receiver) alignment, and sends four different valid height request messages to the sites (one per quadrant). It then checks the appropriate height replies and registers a success indication on the senior director's display. Programs are now being considered for checkout of the present teletype and the future time-division data link subsystems.

### 3. Ground-to-Air Communications

A ground-to-air voice radio system was used for the first time in ESS shakedown tests on 21 June. Circuits were supplied for all intercept directors and intercept technicians. Initial difficulties, mainly in the console installation, were remedied and the system now performs satisfactorily.

In July, frequency-division data link was used for the first time in ESS shakedown tests. In this communication link to interceptors, the computer automatically sends vectoring instructions to the aircraft display (scope or other instruments): the pilot reads the display and maneuvers the plane accordingly. Group 62 supplied a computer program and checkout procedures for this equipment. Satisfactory operation was reported from the beginning.

R.J. Callahan, A. Hingston, J. Malouin, R.B. Paddock, C. Sanders, T.J. Sandy, F. Sweeney, A.M. Werlin

## D. EQUIPMENT DESIGN SUPPORT

This phase of Group 62 activities includes the design and construction of special equipment (mainly for test purposes) to support the work in subsystem integration and maintenance.

### 1. Measurement of Charactron Display Intensity

The intensity of Charactron tube displays in the direction center has been the source of numerous complaints from console operators. While the intensity of the displays can be adjusted to suit the operators, repeated trips by maintenance technicians to open the consoles and regulate the voltage are required. Group 62 undertook the design of a photometer which will enable technicians to adjust the brightness of all consoles to a uniform level.

### 2. Preamplifier for Ampex FR-100

A transistor preamplifier to match phone lines to the newly delivered Ampex FR-100 tape recorder has been designed and built. It is a single transformer, single transistor amplifier, matching the −20 db phone line to the 0 db tape recorder input. The amplifier has a frequency response curve flat from 100 cycles to 10,000 cycles, is stabilized by heavy voltage feedback, and has performed well on live phone lines.

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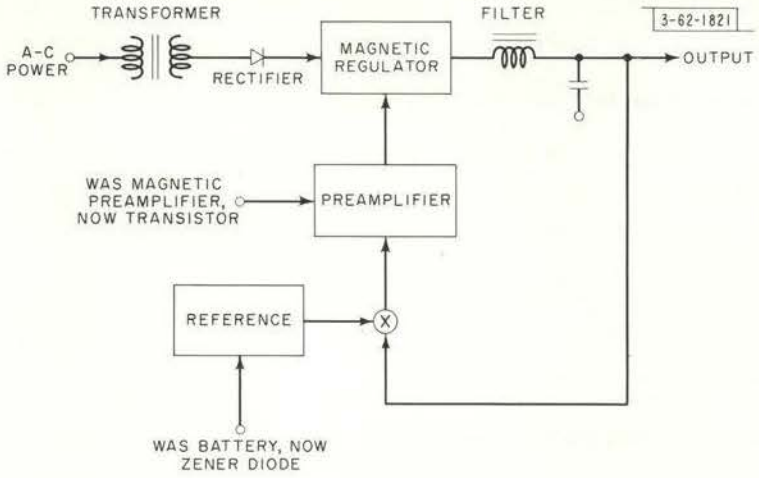


Fig. 62-5. Block diagram of transistor regulated AN/FSQ-7 (XD-1) d-c power supply.

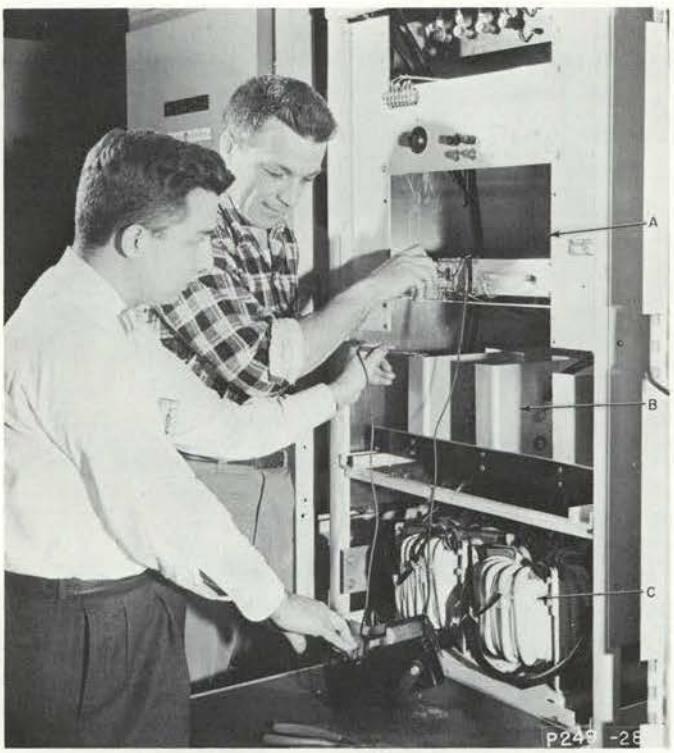


Fig. 62-6. Final circuit adjustment to transistor regulator (A) which replaces magnetic preamplifier in AN/FSQ-7 (XD-1) d-c power supplies (see text). Silicon power rectifier (B) and magnetic amplifier (C) complete the supply.

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### 3. Vector Intensity Modulator

A circuit has been designed for the display frame of AN/FSQ-7 (XD-1) which will equalize the intensity of all vectors and lines in a given display. The chief benefit will be more uniformity in the photographs taken at the central computer by the recording camera. Presently, short vectors or lines are brighter than long ones (see Fig. 62-4). The reason is that all lines are produced with the same total emission: the longer the line, the less concentrated the light. The new circuit will calculate in advance the approximate length of the vector or line and cause an intensification of image proportional to its length.

### 4. DDR Parity Checker

At the request of Group 21, Group 62 has made a parity checker to aid in the adjusting of DDR's (digital data receivers) and to help localize trouble in the subsystem. A light flashes every time an incorrect parity is received from a phone line input. Inserted between the DDR and the LRI (long range radar input) frame, the parity checker is observed for minimum incorrect parities as the DDR is aligned. If excessive incorrect parities persist, trouble is indicated in the DDR or some external circuit. If the parity indication is satisfactory on the checker while incorrect parities are being observed at the LRI frame, LRI drum, or central computer, the trouble is known to be at one of these interior components.

### 5. LRI Simulator

The assembly of a device to simulate LRI (long range radar input) data for test purposes was begun. At the present stage it generates digital words up to 64 bits long at the rate of 1300 bits per second. To this basic unit will be added circuits to control word length, synchronization format length, and automatic parity insertion. When completed, the LRI simulator will enable maintenance personnel to test the performance of the LRI frames independent of external equipment (AN/FST-2, DDT, DDR). It will be possible to introduce controlled errors into the LRI frame to observe its behavior under varying circumstances. The simulator will also be useful in testing other input-output devices, such as a DDR or DDT, when appropriately inserted in the circuit.

### 6. Direction Center d-c Power Supplies

The d-c power for virtually all direction center equipment is furnished by magnetically regulated power supplies (Figs. 62-5, 6). Because of the inherent unreliability of batteries used in the supplies, and the consequent difficulty of adjustment of the supplies, Group 62 began substituting Zener diodes (through which, under certain operating conditions, the voltage remains constant over a wide range of currents) for the batteries, and power transistors for the magnetic preamplifiers. Various bias and gain controls are eliminated; adjustment is easier and maintenance is simpler. This modification has been made to the −15 volt supply in bank A, and will be carried out on the remaining supplies in both the A- and B-banks during coming months.

Excessive power supply drift, previously a problem of long standing, has evidently been stopped. Circuit changes recommended by Lincoln in 6M-4029-S1 (5 December 1955) and



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6M-4338 (16 May 1956) have been carried out by General Electric. Only negligible drift (less than one-half per cent) was observed in several AN/FSQ-7 (XD-1) d-c voltages over a two week period.

### 7. SAGE Power Generation

Group 62 has originated a memorandum (6M-4487) which documents pertinent statements and records concerning the relative merits of SAGE primary power generation at 480 v or 2400/4160 v.* Statements by USAF Hq., USAF-ADES, WE-ADES, Burns and Roe, Inc., Jackson and Moreland, IBM, Western Electric, and Lincoln, made during the period 14 January 1955 to 19 July 1957, are presented in chronological order. Lincoln's position, shared by all technical advisers concerned (Burns and Roe, Jackson and Moreland, Western Electric, and IBM), is stated at the end of the memorandum: that power be generated at 480 v in the interests of economy and reliability.

B. W. Barrett
S. T. Coffin
F. R. Durgin
R. C. Jahn
G. F. Sandy

*The ADES Project Office directed Western Electric in March to redesign SAGE DC and DC/CC power buildings, incorporating 2400/4160 voltage generation.

## ADVANCE DEVELOPMENT

## GROUP 63

PAPIAN, W. N., *Leader*
CORDERMAN, C. L., *Associate Leader*
GOODENOUGH, J. B., *Associate Leader*

ARNOTT, R. J.
BARCK, P. E.
BEHRNDT, K.
BEST, R. L.
BRADSPIES, S.
CLARK, W. A., JR.
COWGILL, URSULA M.
DAVIDSON, G. A.
DOWNING, J. L.
DUGGER, C. O.
DWIGHT, K.
ECKL, D. J.
ELLIS, D. H.
EPSTEIN, M. A.
FADIMAN, J. R.
FARLEY, B. G.
FERGUS, PATRICIA A.
FLETCHER, J. A.
FORGIE, J. W.
FOWLER, P.
FRANKOVICH, J. M.
GILMORE, J. T.
GOULD, R. H.
GUDITZ, E. A.
GURLEY, B. M.
HERNDON, T. O.
HUBER, E. E.
JOHNSTON, R. C.
KIRK, C. T.
KONKLE, K.
LARSON, E. G.
LOEB, A. L.
MADDOCKS, F. S.
MENYUK, N.
MITCHELL, J. L.
NEUMANN, L.
OLSEN, K. H.
PETERSEN, M.
PETERSON, H. P., JR.
RAFFEL, J.
SANTELMANN, W. F., JR.
SARLES, F. W.
SAVELL, R. E.
SMITH, D. O.
UNDERWOOD, D. I.
WEISS, G. P.
WICKHAM, D. G.
WOLD, A.
ZIEMAN, H. E.
ZOPATTI, R. C.

## III. ADVANCE DEVELOPMENT
## GROUP 63

### A. SUMMARY

The 4096-register (64 × 64 × 38) transistor driven core memory (TDCM) is being assembled for TX-2 (the high-speed experimental computer). When the 65,000-register (256 × 256 × 38) core memory which has been operating for several months in TX-0 is transferred to TX-2, a 4096-register (64 × 64 × 20) TDCM will replace it.

The small (50 × 30 mil) cores to be used in the TDCM present a problem of core positioning and retention more serious than that imposed by the 80 × 50 mil cores used in present memory planes. Several methods of locating and holding these small cores have been tested, but the best results have been obtained by etching rectangular openings in a beryllium copper plate to locate each of the 4096 cores of one plane. After the cores are located, a sheet of pressure-sensitive adhesive film is placed over the array so that it contacts every core. When the adhesive sheet is lifted away from the metal plate, the cores remain fixed in position for subsequent wiring.

Successful tests have been made of a remote display system using a Tonotypotron (character writing, half-tone, display tube) to reproduce at Lexington displays generated at Cambridge and transmitted over telephone lines.

Design and construction of the TX-2 has continued and it is expected to be in limited operation next spring. The M, N, and X registers and parity circuits, together with the X-adder have been installed and tested. The permanent power wiring is being tied to the TX-2 frames. Microalloy transistors have made possible an improved flip-flop with excellent rise, fall, and delay times either loaded or unloaded. The same transistor types show promise in other applications such as power or pulse amplifiers and cable drivers.

A memorandum is being prepared which will give programmers a complete description of the TX-2 operation. Meanwhile, the detail design of the instruction code continues.

An appendix to this report to be found on page 26 presents the summary of progress of the Magnetic Materials Section of Group 63. The complete report will be found in Lincoln Laboratory Quarterly Progress Report, Solid State Research, Groups 24, 35, 37, 63, and 310 (Unclassified), 1 November 1957.

W. N. Papian
C. L. Corderman
J. B. Goodenough

### B. MEMORY

The 65,000-register (256 × 256 × 38) core memory continues to operate satisfactorily with the TX-0 computer. Some memory parity errors have been encountered, due largely to cathode flaking and tap shorts in the large driver tubes. Also the current supply which biases the magnetic core switch is temperature sensitive; as much as 100 ma variation in a 24-hour period has been observed. The circuit will be redesigned in an attempt to eliminate these problems. A marginal checking system has been installed and checked out.

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The 4,096-register (64 × 64 × 38) transistor driven core memory (TDCM) is being assembled for use with the TX-2 computer. Excessively high noise levels were detected in the edges of the sense windings in the 64 × 64 planes. By weaving the return wires into the loops of the main sense winding, the two halves of the sense winding were made nearly identical, and the induced noise was reduced to a uniformly low level throughout the plane.

Another 4,096-register TDCM (64 × 64 × 38) is under design. It will provide additional storage for that machine and allow for overlapping memory cycles and a resultant increase in over-all speed.

A prolonged investigation of methods to hold small (50-30 mil) ferrite memory cores during the threading process has led to the successful use of a jig made of etched beryllium copper plate. Previously, a plastic molding had proved satisfactory for holding 80-50 mil cores. The smaller cores introduced new handling problems which made adaptation of the plastic molding to the smaller size impractical. Several methods and materials were explored, the most satisfactory being a thin beryllium copper plate in which rectangular openings were etched. Once loaded on the plate, the array of 4,096 cores is picked up as a unit and held in place by a sheet of pressure-sensitive adhesive film. Four wires are then threaded through each core to make the drive and sense windings of the memory plane.

A temporary jig made of Hypol (a rubber-like substance) was found adequate for limited production of memory planes for the transistor driven core memory for TX-2. Meanwhile the future supply of tested 50-30 mil cores was assured by a new core handler, under construction during the quarter. Initial test results indicate that the machine will probably be more reliable and require less maintenance than the core handler now used.

S. Bradspies
G. A. Davidson
D. H. Ellis
E. A. Guditz
J. L. Mitchell
J. Raffel

## C. DISPLAY

A new 19-inch, character writing, half-tone storage tube is the basis of an experimental remote display * system now in operation. The tube, designated Tonotypotron by Stromberg-Carlson, combines electrostatic and magnetic deflection, has a bright display, and selective control of persistence time.

Test programs have been generated by the Whirlwind I computer in Cambridge, transmitted to Building F, Lexington by telephone line and displayed on the Tonotypotron. During these live tests, magnetic tape recordings were made of the transmission and can now be used for generating the same displays without WW I. The fidelity of the recordings is such that no difference can be detected between the live and canned displays.

H. E. Zieman
R. H. Gould
W. F. Santelmann, Jr.

* Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 June 1957) Section III. D.

## D. TX-2

Design and construction of the high-speed experimental computer, TX-2, continued. The following portions have been completed and tested: the M and N register, M and N parity circuit, X register, X parity, and X adder. It is expected that the program and memory elements will be completed by late Spring and that the computer can become partly operational for test purposes at that time.

### 1. Equipment Installation

a. Program Element: X-Adder

The timing on the X-adder was greatly shortened by the use of two emitter followers per stage to drive the carry chain. It now performs a complete 10-bit addition in less than 1.2 microseconds.

b. Flip-Flop

A design change was made in the TX-2 flip-flop which gives it the excellent unloaded rise, fall, and delay times found in the TX-0 flip-flop, along with the excellent loaded time found in the previous TX-2 flip-flops. The new high-speed design required the use of four L-5134 micro-alloy transistors per flip-flop. Further investigation has shown that this transistor makes possible the design of a similar, less expensive flip-flop for somewhat lower repetition rate applications (up to 2 megacycles), a simple power amplifier and cable driver, and possibly an adequate 0.1 μsec pulse amplifier.

c. Control Element

A test control to exercise selected portions of the computer will be built before detailed design of TX-2 control starts. More information on timing, wiring, and the best logic configuration is hoped for from these investigations. The test control will perform a 9-bit multiplication with one quarter of the TX-2 arithmetic element.

d. Miscellaneous

Two peripheral packages have been designed. The first is a pulse transformer for obtaining −3 volt clock pulses at the register from −12 volt pulses sent from the power clock unit. The second is a power protector plug-in unit, which is used to limit excursions of the −10, −3, and +10 standard computer voltages during failure conditions.

Circuits were being developed for (1) a solenoid driver for the IBM electric typewriter; (2) clutch and brake control circuits for an experimental photoelectric tape reader which employs an electronic magnetic clutch and brake unit; (3) driving circuits for the TX-2 toggle switch storage; (4) a pulse amplifier and a variable delay unit; (5) a delay gauge circuit for stable delays of from 0.2 μsec to several seconds with less than 0.3 per cent variation of delay for 10% change in supply voltage.

### 2. TX-2 Logic

A memorandum is in preparation which will give programmers a complete description of TX-2 computer operation. Work has continued meanwhile on the detail design of the instruction

code. Many small changes have been made in the specification of the instruction code and computer operation as given in 6M-4968, but these are not significant except for the programmers preparing the routines for TX-2.

W. A. Clark, Jr. J. M. Frankovich
B. G. Farley J. T. Gilmore
J. W. Forgie H. P. Peterson, Jr.

## APPENDIX

## SUMMARY OF MAGNETIC MATERIALS SECTION*

This report covers the period from 1 June through 31 August 1957.

### VII. Magnetic Materials

In order to prepare magnetic materials with optimum properties for a variety of engineering components, it is necessary to study not only the problems associated with materials processing, but also the relationships between the desired engineering parameters and the chemical constitution and physical state of the materials. In past quarters attention has been directed primarily to the memory-core application for digital computers: the ceramic facilities have developed suitable processes for several memory-core materials and have supplied electrically tested cores for several Lincoln Laboratory digital-computer memories, including the 2.5 megabit memory currently installed in Group 63's TX-0 machine; the engineering parameters have, with the aid of microscopic theory, been theoretically expressed in terms of more fundamental constants of the material, including dimensions and other physical characteristics. Since many of these more fundamental constants are purely phenomenological, work was also initiated to study the relationships between these constants and the chemistry of the materials. As a background for these investigations, attention has been called to the relationship between lattice symmetry and the stability of the electrons responsible for magnetism. During this quarter a study of the system $Li_xNi_{1-x}O$ has been completed. This system has been shown to be ferrimagnetic in the range of compositions $0.3 < x < 0.5$, a maximum magnetic moment per gram of 31 c.g.s. $cm^3/gm$ being observed at $x = 0.46$, a maximum ferrimagnetic Curie temperature of 241°K being observed for the composition $x = 0.41$.

A study of the perovskite system $LaMnO_3$-$LaNiO_3$ has been started. The quantitative dependence of the crystallographic properties of $LaMnO_3$ on $Mn^{4+}$ concentration have been worked out, and preliminary measurements of magnetic properties suggest ferromagnetism not only in the compositional range with 75% of the small cations $Mn^{3+}$, but also in the vicinity of 50-50 $LaMnO_3$ and $LaNiO_3$. An interpretation of these results suggests that of the possible indirect-exchange mechanisms between cations on opposite sides of an oxygen ion, a modified super-exchange model is the most accurate.

These conclusions are also supported by a theoretical interpretation of the peculiar magnetic properties of the perovskite-type mixed crystals $La_{1-x}Sr_xCoO_{3-\lambda}$ which was worked out this

*cf. Lincoln Laboratory Quarterly Progress Report, Solid State Research, Groups 24, 35, 37, 63, 310 (Unclassified), 1 November 1957.

quarter. The interpretation is based on the fact that internal, crystalline electric fields may be sufficiently strong to destroy Hund's highest-multiplicity rule.

In the ceramics laboratory the processing procedures for thermistors, filter ferrites, and garnets are being studied. Before investigating the dependence of the engineering parameters on chemical constitution, it has been necessary to learn to control the density and homogeneity of large slabs of material. In both the filter ferrites and the garnet $Y_3Fe_2(FeO_4)_3$, the problem has been demonstrated to consist of finding a process to obtain a homogeneous, dense piece with low ferrous-iron content.

A program of study of the various electric and magnetic properties of a single crystal as a function of temperature has also been started: this study will investigate the equation of motion on which current theories of dynamic, magnetic processes depend. The purely phenomenological Landau-Lifshitz equation which presently serves as the basis for most dynamical theories needs checking, and probably revision. During this quarter the magnetic anisotropy from below 4°K to the Curie temperature has been measured for several single crystals, and a sharp discontinuity in the range 9 to 11°K has been observed in one of them. Several measurements have been made to investigate the origin of this discontinuity.

## VIII. Thin Magnetic Films

The large, general-purpose, digital computers used in air defense require individual components of extreme reliability, high speed, easy assembly into large groups, and low cost. Traditionally, the computer memory has determined the limitations in the speed and capacity of these machines. The coincident-current, random-access memory using ferrite toroids as the bistable memory element was first developed here to meet this problem. However, a study of the inherent speed-power limitations of these toroids led to the conclusion that a thin (~1000Å) magnetic disc of magnetic material instead of a ferrite toroid would provide a bistable element with a speed-power limitation for the individual component some $10^2$–$10^3$ improved. A program was therefore initiated to study the properties of thin permalloy discs, and their dependence upon and control by processing procedures. Simultaneously an engineering program was begun to develop circuitry and packaging techniques which can exploit the properties of the new components.

There are four principal problems which require investigation: the magnetization-reversal process, including an investigation of the magnetic equation of motion; the origin and control of magnetic anisotropy; the nature of domain walls in thin films and methods of eliminating the domain-wall processes; production of uniform arrays.

During this quarter the instrumentation for switching thin magnetic films and observing voltage-output signals in the 1–10 mμsec range has been completed; preliminary experiments indicate at least order-of-magnitude agreement with predictions based on the Landau-Lifshitz dynamical equation. Instrumentation has also been completed for ferromagnetic-resonance studies in the same frequency range.

Work on the origin of the uniaxial anisotropy present in permalloy films indicates that the presence of a magnetic field during film formation only orients the direction of the unique magnetic axis. The magnitude of the uniaxial anisotropy has been correlated with the presence of

linear defect bands which appear after etching, the type of correlation for specimens with positive magnetostriction differing from that for specimens with negative magnetostriction.

The domain walls in thin films have been studied by Bitter-pattern techniques, and these have been interpreted by taking account of the strong shape anisotropy of a magnetic film.

Finally, compositional studies have shown that the present lack of uniformity from thin disc to thin disc in a given array is due to differences in chemical composition, this difference in composition existing even though all discs are simultaneously formed during the same evaporation.

## IX. Transistors

The transistor is a potentially important component for digital computers because of its size, reliability, long life, and low power requirements. However, the device has, until recently, been limited by speed of response and by power-handling capacity. Since considerable effort is being expended elsewhere in the country on the development of improved transistors for the more conventional applications, such as amplification, the transistor effort in Group 63 has been mainly devoted to the study of those mechanisms which determine the performance and reliability of the transistor when used as a switch in computer-type circuits.

In the interest of simplicity, and therefore of reliability, it has appeared preferable to drive the transistor switch to saturation when putting it into the "on" state. In a saturated switch, hole storage is an important factor limiting the switching speed. Therefore considerable effort has been expended to obtain a better understanding of the nature of this phenomenon. It has been shown that the hole-storage time is determined by the minority-carrier injection efficiency of the emitter as well as by the effective base lifetime of minority carriers due to both surface and bulk effects. In grown and alloy junction transistors, the injection efficiency is sufficiently high that the hole-storage time constant is found to be essentially equal to the effective base lifetime of minority carriers. In transistors of the surface-barrier type, on the other hand, the injection efficiency plays a predominating role.

The transient response of homogeneous and graded-base transistors has also been studied by using Laplace transforms to solve the diffusion equation.

Some life-test data has been obtained for surface-barrier transistors in operating systems.

J. B. Goodenough
R. J. Arnott
P. E. Barck
Ursula M. Cowgill
C. O. Dugger
K. Dwight
D. J. Eckl
E. E. Huber
R. C. Johnston
C. T. Kirk
E. G. Larson
F. S. Maddocks
N. Menyuk
D. O. Smith
G. P. Weiss
D. G. Wickham
A. Wold

## ESS SHAKEDOWN TESTING – WWI AND MTC OPERATION

### GROUP 64

RICH, E. S., *Leader*

DAGGETT, N. L., *Associate Leader*

ALCOTT, W. E.
ALLEN, D. F.
AUFDERHEIDE, D. R.
BLACK, M. D.
BRIDGE, H. P.
BROOKS, EMY
BRYAN, JEAN C.
CAHILL, J. J., JR.
CASE, A. W.
CHOMSKY, CAROL S.
DECOF, D. N.
EARL, LOIS M.
FITZPATRICK, VIRGINIA
GATES, E. K.
GILLIS, C. V.
GRANDY, C. C.
HEALY, L. D.
HODDER, J. C.
HOLMES, L. L.
HOPKINS, F. W.
HUDSON, NANCY
HUGHES, A. D.
JONES, N. T.
LAFFERTY, E. L.
LIN, C. S.
MERCER, H. F.
MONAHAN, J. H.
MORRISON, D. A.
MURPHY, P. J.
NICHOLS, J. R.
NORCOTT, L. H., JR.
OCKENE, N. J.
OGDEN, W., JR.
OLSEN, S. C.
ROBERTS, J. E.
ROBERTS, T. A.
ROWE, A. J.
SMALL, C. E.
STOCKEBRAND, T. C.
STYLOS, P.
THOMAS, D. J.
VANDERBURGH, A., JR.
WOODWARD, W. B.
ZIEGLER, H. L.
ZULLO, W.

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| Test# | Standard Input Data | Times Performed | Primary Functions Tested |
|---|---|---|---|
| 14 | Simulated | 5 | Weapons direction (introduction of Package D to the system). |
| 15 | Simulated | 3 | Intercept simulation and intercept direction; integrate additional operators; first attempt to collect data for analysis. |
| 16 | Live | 4 | External facilities such as interceptor airbases, weather stations, and AADCP; get preliminary information on live weapons operation. |
| 16A | Mixed | 2 | Same as #16, but inputs more complex. |
| 17 | Live | 3 | Same as #16, but inputs more complex. |
| 18 | Mixed | 2 | Weapons direction; rigorous system verification. |
| 19 | Mixed | 2 | Similar to #18. |
| 20 | Live | 2 | Entire system; full scale comprehensive air defense tests. |
| 21 | Live | 2 | Similar to #20. |
| S7 | Simulated | 1 | Manual initiation. |
| OIST-4* | Ampex/Simulated | 2 | Tracking and identification with minimum stress on weapons direction (53 tracks, 10 interceptions). |
| OIST-5 | Ampex/Simulated | 3 | All sections, moderate load (65 tracks, 20 interceptions). |
| OIST-6 | Ampex/Simulated | 3 | All sections, moderate to heavy load (75 tracks, 30 interceptions). |
| Special | Simulated | 1 | Air surveillance. |
| Special | Simulated | 1 | Calculation of offset points. |
| Special | Simulated | 1 | Operator training. |

*operator integration shakedown test.

Fig. 64-1. ESS system tests performed with Package D, 1 June – 31 August.



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# IV. ESS SHAKEDOWN TESTING – WWI AND MTC OPERATION GROUP 64

## A. SUMMARY

Package D of the direction center active (DCA) program was delivered to Group 64 and tested throughout the quarter. The air defense functions added in Package D are weapons assignment, intercept direction, and antiaircraft direction; these comprise the complete weapons direction portion of the DCA program. Analysis of test results showed that the fundamentals of these functions are in accordance with design specifications; further testing is needed in order that weapons directors and intercept directors can learn to handle heavier loads under varying conditions. The Memory Test Computer (MTC) continued its support of ESS system shakedown testing by reducing test data for analysis and producing simulated-data-generation tapes. The maintenance of Whirlwind I (WWI) equipment was continued.

This quarter marked the first use of live interceptors in ESS shakedown testing. After a few weeks of familiarization with their positions, intercept directors were able to vector interceptors (mainly F86's) into successful final tactics against live strike aircraft (mainly B-47 and B-52 types supplied by the Strategic Air Command). In support of the intercept direction function, the Hanscom and Weymouth Airbase alert centers were integrated into the system, as was the Ft. Banks Army Air Defense Command Post (AADCP). Ground-to-air voice link and data link were successfully used for the first time. Difficulties were encountered in program and equipment operation and in personnel performance at both the direction center and the interceptor airbases. By the end of the quarter, many such difficulties had been located and eliminated, and it was concluded that the functions assembled in Package D are capable of meeting design specifications under normal or heavy load conditions; a continuing improvement in operator proficiency is necessary to realize this capability.

Faced with an increasing workload of ESS shakedown data which cannot yet be shared with the new IBM 704, the MTC section has attempted to improve its performance in reducing data and producing simulated-data-generation tapes. Personnel training has been intensified, marginal checking lines added, and circuits and equipment installed, replaced, or modified.

E. S. Rich
N. L. Daggett

## B. ESS SHAKEDOWN TESTING

### 1. General Plan

ESS equipment, computer programs, and Air Force operators are combined in a series of system shakedown tests to produce data for the diagnosis and correction of any faults that may indicate lack of compliance with specifications. Particular air defense functions are examined in each system test as the computer programs for them become available. The tests become more comprehensive and more complex as each package of the direction center active (DCA) program is received. Thirty-seven system tests were performed using DCA Package D which was delivered on 1 June. The tests performed are described in Fig. 64-1, and a breakdown of ESS system testing time is given in Fig. 64-2.



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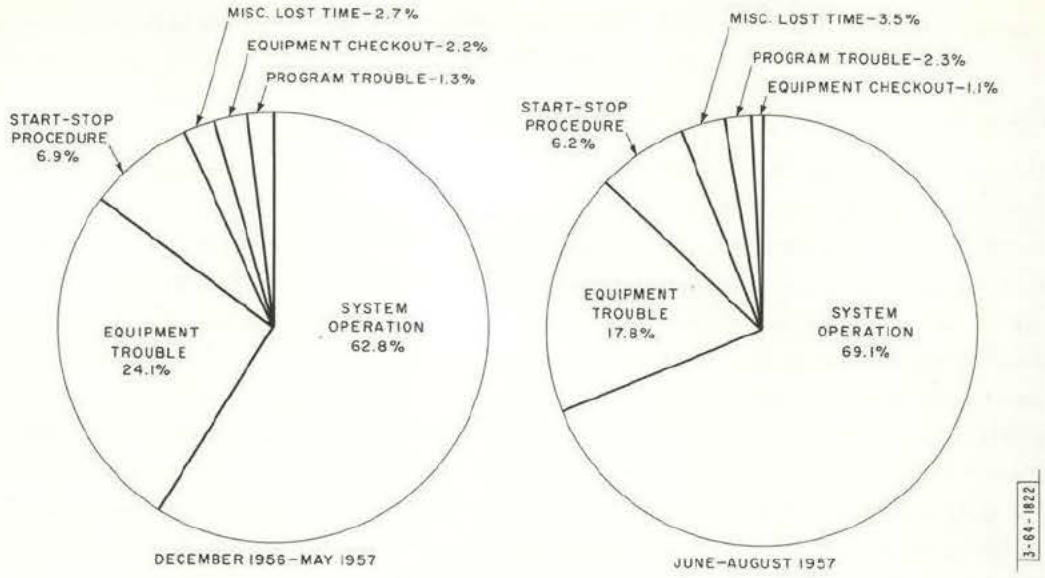


Fig. 64-2. Breakdown of ESS system testing time.

The functions included in Package D of the DCA program are:

Radar Inputs
Manual Initiation
Automatic Tracking
Data Simulation
Recording
Automatic Initiation
Track Monitoring
Height Finding
Manual Inputs
Identification
All Digital Displays
Weapons Assignment
Intercept Direction
Antiaircraft Direction

(Weapons Direction: added with Package D)

## 2. Test Implementation

The advanced stage of capability (and complexity) represented by Package D called for increasing use of live aircraft for the tests. In particular, the weapons assignment and intercept direction functions required live interceptors for effective measurement and analysis of system performance. The first live interception controlled by ESS was carried out on 21 June: the interceptor was successfully vectored to a zero-velocity simulated target. In August, eight out of twelve tests made use of live aircraft: 86 bomber sorties were flown and 106 interceptor sorties were carried out. Nearly all of the strike aircraft were B-47 and B-52 types supplied by the Strategic Air Command. Interceptors (predominantly F86's) were scrambled from Portsmouth, Weymouth, Otis, and Westover. The interceptors from the Portsmouth base were on temporary assignment from Hanscom Airbase where runway repairs were being made.



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Besides providing necessary experience for operators in the weapons direction function, the use of live aircraft made possible the testing of external parts of the system, such as airbase alert centers, Army air defense command posts (AADCP), ground-to-air data link, and ground-to-air voice radio link. In July, the Ft. Banks AADCP was integrated in ESS; The Hanscom Airbase alert center was integrated for weapons status input information and interceptor scrambles; and the Weymouth Airbase alert center was similarly integrated. The frequency-division ground-to-air data link enabled the computer to transmit vectoring instructions automatically and directly to the interceptor pilot. Twenty-six Air Force operators were added to fill new positions called for at weapons direction consoles and in the expanded manual inputs and identification sections.

Of the problems encountered in carrying out shakedown tests, one which became especially troublesome was excessive scramble time, in some cases as high as 20 minutes. From the shakedown testing point of view, excessive delays in getting the interceptors airborne resulted in the target aircraft changing course to the next leg of its planned flight path before the interceptor could reach altitude and attack. Valuable test data was thus lost. Among the reasons for these delays were the following: (1) lack of experience and unfamiliarity with procedures on the part of both direction center and airbase personnel; (2) inadequate facilities at airbases for passing scramble messages from alert centers to pilots; (3) necessity for aircraft to conform to local regulations in being cleared for take-off; (4) errors by operating personnel; and (5) malfunction of equipment. Corrective action taken to date has improved scramble performance; continued emphasis will be placed on further reducing the delays.

### 3. Test Results

Package D of the DCA program was introduced to ESS shakedown testing at the first of the quarter. The functions of Package B had undergone rigorous testing and had been found capable of supporting the weapons direction functions introduced with Package D. Because weapons assignment and interceptor direction required an expansion of the system involving a number of new operators, it was expected that many minor defects would be discovered during testing. The principal objectives, therefore, were to detect these deficiencies and correct those which prevented effective operation or which precluded collection of data for quantitative analysis. In June, only 2 of 12 tests used live aircraft; in July, 5 out of 13 tests were live; and in August, 8 out of 12 were live. The month of June can thus be considered a period of introduction to Package D, while July marked the beginning of intensive tests to make fuller use of the weapons direction capability.

A number of significant accomplishments were made during the month of July. A program-equipment incompatibility in the use of ground-to-air data link was eliminated by a revision to the program, and the first successful live interception using this facility was accomplished. One intercept director successfully vectored two voice controlled interceptors simultaneously, with final phase for the two intercepts occurring within three minutes of each other. Procedural difficulties in the use of airbase alert centers were reduced to the extent that interceptor scrambles and recovery were possible under IFR conditions. Intercepts were conducted in which both target aircraft and interceptor were Raydist equipped, yielding valuable data for system analysis.



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A highly satisfactory mission was run on 26 July. On that date, seven successful interceptions were carried out by ten interceptors against five strike aircraft. Eight F-86L's, one F2H, and one F4D were scrambled against three B-50's, one C-131, and one P2V. Two interceptors made successful re-attacks on the same target.

During August, when major emphasis was being placed on the functions of weapons assignment and intercept direction, certain problems in program, equipment, and operational procedures caused a reduction in the number of successful interceptions. Those that had significant effects on system performance and were considered critical problems include:

(1) Offset points for intercept vectoring had been incorrectly calculated.

(2) Winds-aloft data had been incorrectly interpreted: both this and (1) had the effect of directing the interceptor to an erroneous position on roll-out from the final turn so that the desired 90° beam crossings could not be obtained.

(3) Interceptors were scrambled with excessive delay, as high as 20 minutes (see Section B. 2 of this report).

(4) A faulty switch action had altered instructions in the computer program and resulted in erroneous displays and improper responses to switch actions.

Remedial measures were taken to correct the above discrepancies, and in the latest live tests for which corrections to all outstanding critical program errors had been made, visual

Fig. 64-3. Dais, Weapons Room, ESS. From a raised platform in the middle of the weapons room, the senior director (fourth from left), senior weapons director (fifth from left), and air tactics officer (second from left), control and supervise the air battle. Each is assisted by one technician. The senior director is in over-all charge of the direction center; one of his specific duties is to coordinate antiaircraft assignments with interceptor assignments. One of the senior weapons director's chief functions is to equalize the load among the weapons directors; he assigns strikes to them by switch action. The air tactics officer is responsible for raid forming; that is, he recognizes individual tracks whose heading, speed, and proximity to each other indicate a number of aircraft acting together as a unit. When these aircraft are identified as hostile, a raid is formed and special displays are generated.

In this and the following photographs, the technicians shown assist the officers by taking switch actions to call up digital displays, acknowledge incoming assignments, and transmit information to other stations or to the computer. Interceptors are scrambled by voice command.

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observations indicated a marked improvement in the number of cases where interceptors were properly vectored by the computer program. Data from these missions is being analyzed for verification of these observations.

a. Weapons Assignment (see Figs. 64-3 and -4)

The principal responsibilities of a weapons director are to: (1) Insure that sufficient weapons are available to meet any existing or potential threat; (2) examine each threat; (3) commit weapons against specific targets; and (4) assign responsibility for the execution of the mission to an intercept director. In addition, weapons directors designate aircraft for combat air patrol, return-to-base, deployment, and flight following.

Responsible for weapons assignment are the senior director, the senior weapons director, and the weapons directors. In a typical sequence of operation, a weapon director decides to commit weapons against a target, scrambles interceptors, and assigns responsibility for the monitoring of the interception to an intercept director. On occasion, the senior director or the senior weapons director makes the decision to commit weapons against a target and, by switch action, assigns responsibility for the target to a weapons director. These personnel have access to situation and digital displays, keyboard switches, alarms, and telephone lines which supply them with information necessary for making decisions and which allow them to communicate with the computer and with each other. In addition, each has a technician available to assist him.

By mid-August, when many of the discrepancies in the system had been located and eliminated, the weapons assignment personnel had gained proficiency to the extent that reasonable

Fig. 64-4. Weapons Room, ESS. There are 50 consoles in the weapons room. Two weapons direction teams are shown here: each consists of a weapons director (WD), four intercept directors (IND), and their technicians. The WD of the first team is shown with his technician in the center of the photograph. The other WD is at the opposite end of that row of consoles. After scrambling interceptors, each WD assigns responsibility for monitoring the interception to one of the IND's. The officer and airman situated between the WD's are the antiaircraft director and his assistant. By switch action the AA director may add or delete tracks to be sent by the computer to Army air defense command posts.

On the raised platform is the tactical channel assignment panel where ground-to-air radio frequencies are selected, previous to each test, for communication between intercept directors and interceptors.



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work loads could be managed under standard procedures. By the end of the quarter it was concluded that the functions assembled in Package D are capable of meeting design specifications under normal or heavy load conditions; a continuing improvement in operator proficiency is necessary to realize this capability.

b. Intercept Direction

The intercept directors control an interception mission after a weapons director has selected, assigned, and scrambled interceptor aircraft against a strike. Five intercept directors, each with an intercept technician, constitute a team under the supervision of a weapons director. The intercept directors select and insert parameters, such as altitude, speed, and tactics, into the computer by keyboard switches. The computer provides vectoring instructions, transmitted to the interceptor pilot by data link during the ground control phase of the mission. In the absence of data link, the intercept directors transmit vectoring instructions by voice radio. Upon completion of the mission, ground control is resumed for return-to-base. As in the case of the weapons assignment function, the intercept directors were introduced gradually to their responsibilities and procedures. By August, when some of the difficulties mentioned in Section 2 above had been corrected, a significant increase in the number of successful interceptions was observed. Continuing instruction of intercept directors is planned.

c. Antiaircraft Direction

The antiaircraft direction section supplies information to, and coordinates the operation of, each of the antiaircraft defenses within the sector. The computer program selects tracks to be told to the Army air defense command post (AADCP), assembles the proper information on these tracks, produces the messages, and transmits them to the AADCP. By keyboard switch action, an antiaircraft director may add or delete tracks to be told to the AADCP. The program also processes replies from the AADCP containing fire-unit operational status or engagement status information for pushbutton insertion.

Fig. 64-5. Weapons Room, ESS. A weapons director and his technician are shown in the foreground, with two intercept directors and their technicians in the background. The WD has instructed his technician to assign an interception to one of the IND's for monitoring. The IND on the right is selecting a ground-to-air radio transmitter site for best communication with the interceptor. The IND and pilot will be in voice contact throughout the mission.

Using a headset, each operator can talk to any other operator in the direction center by dialing his console number. In addition, each operator is connected by direct voice circuits to other positions of special importance to him, usually four in number.



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Fig. 64-6. Air Surveillance Room, ESS. The air surveillance room contains a number of functions which combine to present the total air situation to the weapons room. Shown are two tracking teams, headed in the left and right foreground by tracking supervisors. Beyond the supervisor in each row are five track monitors who restore tracks and data that have become separated or lost and return them to the automatic tracking function of the program by light gun action. A third row of consoles off the photograph to the left is manned by track initiators and height technicians. Behind the camera on a raised platform sit the tracking officer, the initiation supervisor, the initiation area discriminator, and the air surveillance officer who supervises all of the above functions.

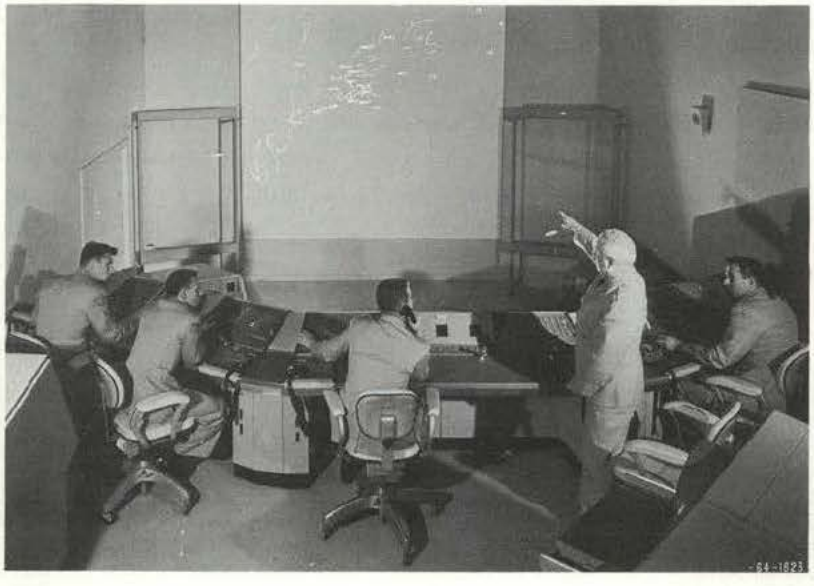

Fig. 64-7. Sector Command Post, ESS. In a separate room of the direction center the sector commander and his staff follow the air battle from a projected summary picture of the air situation, updated every 30 seconds. Other situation and digital displays are also available on consoles. The command post exercises over-all supervision, planning, and control of the air defense of a sector and (in the operational SAGE system) will coordinate functions with adjacent sectors and higher headquarters.

The Ft. Banks AADCP was the first to be integrated into ESS, participating for the first time on 12 July. Later in the month Army personnel arrived at Lincoln to begin training to man AA stations in the direction center. By the end of the quarter the Army operators were reasonably proficient and a number of program and equipment errors had been corrected; as a result, the AADCP's were reporting a large percentage of simulated kills. Problems still to be worked out lay largely in the area of communications between the direction center and the Army air defense command posts.

d. Overlap Tracking

An examination of a significant sample of track data has shown that returns from two heavy radars fall within the small search area* at least 80% of the time. It is possible that the data for the remaining 20% may fall within the allowable limits for separation, but it could not be determined from the analysis used. This registration is considered satisfactory for system use. A theoretical study of the accuracy with which the computer program provides overlap data registration has continued and some significant results have been obtained. Hand calculation for ten points in space chosen to be within the coverage of the Bath and South Truro radars and to represent aircraft at known altitudes were made to determine the errors introduced in mapping the radar-reported positions of these points onto the two-dimensional ESS system plan. The results verified that errors introduced by quantization and by the transformation process are within specifications. Furthermore, the separation between locations of these points as reported by Bath and South Truro and projected into the ESS plane is also within specifications. In the second phase of this study, the identical points will be processed by the DCA program within the computer for comparison with the hand calculated data.

e. Height Finding

The performance of the height finding function has been satisfactory enough to support interceptions in shakedown testing. Because of certain observed discrepancies, however, investigations are continuing to locate and correct sources of error. It has been found that the positional error in the radar data after applying the correction for aircraft height is relatively slight for height finder inaccuracies of ±2000 feet or less, but begins to assume importance at short range with a height finder inaccuracy of ±3000 feet.

In addition to seeking the causes for such errors, the investigations will attempt to answer such questions as: whether a track position should be extrapolated to compensate for delays in the transmittal of requests to a site; and whether height requests should be generated on tracks with poor track merit. Members of Group 22 and Division 4 are assisting in this study.

| | | | |
|---|---|---|---|
| C. C. Grandy | Carol S. Chomsky | R. D. Buzzard | J. N. Monahan |
| C. S. Lin | Lois M. Earl | D. R. Aufderheide | J. R. Nichols |
| J. C. Hodder | Virginia Fitzpatrick | H. P. Bridge | P. Stylos |
| W. Ogden, Jr. | Nancy Hudson | Jean C. Bryan | W. B. Woodward |
| J. J. Cahill, Jr. | R. F. Hudson | A. W. Case | H. F. Mercer |
| A. Vanderburgh, Jr. | D. J. Thomas | N. T. Jones | J. E. Roberts |
| Emy Brooks | M. D. Black | E. L. Lafferty | T. A. Roberts |

*The small search area is a circle one mile in radius, used in the program for correlating radar data with tracks but not displayed.

## C. MEMORY TEST COMPUTER

Increased demand has been placed on MTC to reduce data and produce simulated-data-generation tapes in support of ESS shakedown testing. The computer work load has increased as shakedown tests have proceeded, and the recently acquired IBM 704 is not yet ready for these tasks. It has therefore been necessary to improve the efficiency of MTC by intensifying the training of operating and maintenance personnel, increasing preventive maintenance by installing new marginal check lines, and revising circuits and equipment for better performance.

### 1. Training Program

An intensified training program for MTC staff and technicians was begun on 12 June with classes once a week for regular personnel and more often for newcomers to the section. The subject matter gave the students a brief history and background on MTC, its general physical layout, and the proper procedure for operating the computer.

### 2. Computer Operation and Maintenance

In a continuing effort to find the source of interrupting incidents and increase the reliability of the computer, a number of improvements were made during the quarter. A special effort to report even the most trivial of interrupting incidents has succeeded well: such incidents are occurring at the rate of about 40 per week for a mean free time of 3 to 4 hours between incidents. In a continuing effort to equip the computer with a complete system of marginal check circuits, the installation of about 50 new lines was begun. One particularly troublesome source of error was found on the program counter. Interference from a nearby radar test station was somewhat reduced by the judicious placement of metallic foil shielding.

### 3. MTC Operation Log

MTC operation and reliability for this quarter were as follows:

| | |
|---|---|
| Scheduled Computer Hours | 2085.2 |
| Per cent Good Time | 90.1 |
| Mean Free Time (Hours) | 5.4 |
| Average Lost Time per Interrupting Incident (Hours) | 5.3 |

## D. WHIRLWIND I

Group 64 is responsible for maintaining WWI and its associated input-output equipment. Of the items reported during the quarter, the performance of the Analex line printer is worthy of note: in a comparison test the line printer processed 4000 octal registers in 115 seconds, while a conventional delayed printout by magnetic tape and typewriter required over 40 minutes.

WWI operation and reliability for this quarter, measured at one week intervals, were as follows:

| | |
|---|---|
| Scheduled Computer Hours | 1477.5 |
| Per cent Good Time | 96.3 |
| Mean Free Time (Hours) | 29.3 |
| Average Lost Time per Interrupting Incident (Hours) | .68 |

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VACUUM TUBES

GROUP 65

YOUTZ, P., *Leader*

CLOUGH, T. F.

PALERMO, J. S.

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# V. VACUUM TUBES
## GROUP 65

## A. SUMMARY

Stromberg-Carlson produced 99 acceptable Charactrons at the same production rate as the previous quarter. Machlett Laboratories produced 40 acceptable Scriptrons (their equivalent of the Charactron produced by Stromberg-Carlson). The cutback in demand for these tubes threatens the continuous and economic operation of the production lines of two sources. The operational life data of the Charactron tube in XD-1 has leveled off for the past several quarters and indicates an expected life of 5000 hours operation limited by cathode depletion and deterioration. Continuing studies indicate that bariated-nickel cathodes are capable of a very satisfactory life under more rugged conditions than are the presently used oxide cathodes. In addition, they might improve some special Charactron operational problems (e.g., spot and vector defocussing). However, bariated-nickel cathodes should not replace the oxide cathodes until some production tubes of a commercial vendor are made with B-N cathodes and given operational life in display consoles.

Production of Typotrons at Hughes Products continued at a reduced rate. Meanwhile, Machlett Laboratories has been attempting to qualify as second source and prototype production should start early next quarter. The operational life of the Typotron continues to climb each quarter, due in part to an increase in the impedance of the $A_3$ voltage supply in the display consoles. The present expected life of a Typotron is 6000 hours, a figure which may improve one or two thousand hours during the next two quarters. The two cathodes in the Typotron are not the end-of-life component. Barta Building life tests substantiate the fact that the storage surface deteriorates before the cathodes fail.

Both General Electric and Raytheon have been producing the low-power twin triode 6414 satisfactorily with an adequate inventory at IBM-Kingston. Raytheon has an impending problem of getting an approved melt of cathode material for future protection.

Both Sylvania and Bendix have the production of the dual-control pentode (6888) under control.

Tung-Sol ceased production of the 5998 with an inventory of 25,000 tubes. Chatham, a wholly owned division of Tung-Sol, will make all future 5998's. There is no second source for the tube. Chatham progress will be monitored to make sure that they will be producing quality tubes before Tung-Sol inventory is depleted.

The major symptom of failure in the receiver tubes removed from AN/FSQ-7 (XD-1) continues to be low output or no output. The 6161 used as a deflection driver in the display consoles continues to have a high failure rate. This tube has had special attention at RCA and IBM-Kingston.

P. Youtz

## B. DISPLAY

### 1. Charactron

a. Production

Stromberg-Carlson continued at the production rate of the previous quarter because of reduced demand and the sharing of the load with the second source – Machlett Laboratories. The

GROUP 65

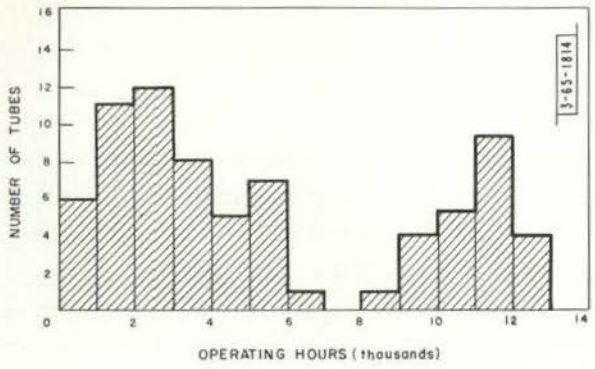


Fig. 65-1. Distribution of Charactron operating hours in AN/FSQ-7 (XD-1) consoles.

| Life-Test Hours Before Failure | | Reason for Failure | | | | |
|---|---|---|---|---|---|---|
| Filament | d-c | Low Emission | Non-uniform Cathode | Beam Shift | Won't Cut off | Other |
| 9507 | 6514 | X | | | | |
| 11117 | 10155 | | X | | | |
| 10100 | 9370 | | X | | | Poor brightness |
| 9827 | 8267 | | X | | | |
| 9568 | 7484 | | X | | | |
| 3494 | 3473 | | | | | Astigmatism |
| 763 | 735 | | X | | | |
| 5767 | 4875 | X | | | | |
| 7045 | 6684 | | | X | | |
| 11113 | 9441 | | X | | | |
| 4292 | 3663 | X | | | | |
| 9619 | 7508 | X | | | | |
| 9734 | 5578 | X | X | | | |
| 858 | 840 | | | | | Unknown |
| 599 | 519 | | | | X | |
| 7840 | 7066 | | X | | | |
| 2695 | 2604 | X | | | | |
| 4396 | 4301 | | | | X | Gassy |
| 5763 | 5025 | X | | | | Broken socket |
| Unknown | | | X | | | |
| Unknown | | | X | | | |

Fig. 65-2. Causes of failure in Charactrons removed from life test June – September 1957.

two major production defects were screen quality and helical-accelerator breakdown. Stromberg-Carlson's June production efficiency was the highest to date with a realization rate of 93.3%. The realization rate for the entire quarter was 80.5%.

During this, their second production quarter, Machlett solved their previous difficulties of peeling aluminum-dag band. They are now conducting their own acceptance tests. Machlett achieved a realization rate of 88.8% for the quarter.

b. Life-Test Program

Stromberg-Carlson and Group 65 have been accumulating Charactron life data on their life-test racks and operational life in the display consoles at XD-1 and SAGE sites. No operational data has been released from the sites.

The life-test racks at Hazeltine have been relocated at the newly-formed Display Tube Group of IBM at Kingston for the sample life testing of recent production tubes of Machlett Laboratories.

Two prototype tubes of Machlett Laboratories on test at Stromberg-Carlson have each accumulated about 4500 hours. Eleven recent production Charactrons of Stromberg-Carlson have also accumulated an average of about 4500 hours. The Group 65 life racks contain nine 19-inch display tubes with an average of 11,640 hours. Four Stromberg-Carlson Charactrons have an average of 13,941 hours and an MIT tube has 20,111 hours. All five tubes still pass all of the acceptance tests. Four experimental MIT Charactrons with bariated-nickel cathodes have an average of 6998 hours.

The filament hours of the 74 Charactrons in AN/FSQ-7 (XD-1) as of 1 September 1957 are distributed as shown in Fig. 65-1.

The 21 Charactrons removed this quarter failed for the reasons given in Fig. 65-2.

In Fig. 65-3 the average hours of Charactrons removed from AN/FSQ-7 (XD-1) are tabulated by quarters.

c. Oxide-Cathode Studies

Of the 39 tubes originally placed on life test to study different activation schedules and cathode materials for oxide-coated cathodes, 8 still pass the original specifications and had an average life of 12,696 hours on 31 August 1957. Four tubes are of the same lot and category which consist of tubes with RCA guns and RCA cathodes processed on a long exhaust schedule.

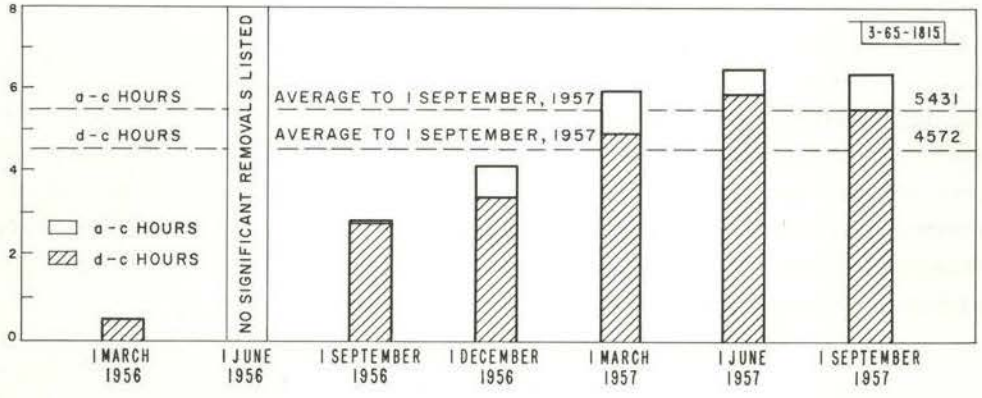


Fig. 65-3. Average hours of Charactrons removed from AN/FSQ-7 (XD-1) during 1956 and 1957.

This lot and category have consistently looked better than the others throughout the life-test program. The remaining four tubes are spread among three categories of cathodes and processing methods.

d. Bariated-Nickel Cathode Studies

Nineteen 2-inch diameter B-N tubes of the 93 tubes originally on life continue with an average time of 9979 hours. Four of these tubes have the same cathode formulation as three of the 19-inch display tubes with B-N cathodes. No experimental B-N tubes have been made for the past 6 – 8 months. The life-test results show that certain categories of B-N cathodes are capable of very satisfactory life. Since B-N cathodes are more rugged than oxide cathodes, they offer promise of improving some special Charactron operational problems (e.g., spot and vector defocussing). Operational tests of Charactrons with B-N cathodes in display consoles will be required for verification. During the next quarter the AN/FSQ-7 (XD-1) operational life data of Charactrons with oxide cathodes will be studied to determine one of the following courses of action:

(1) Continue the B-N development program at Lincoln and make a series of 19-inch Charactrons for operational use in AN/FSQ-7 (XD-1) according to the methods detailed in our written process specifications.

(2) Encourage the manufacturers of Charactrons to take up this work with the aid of a production refinement contract from IBM.

(3) Stop any further work on B-N cathodes for the moment since the oxide cathodes have been giving a fairly satisfactory length of life and because the introduction of a new type of cathode in a production line poses unknown risks.

## 2. Typotron

The factors affecting the reliability of storage tubes for data display in AN/FSQ-7 were studied through life-test programs and operational data from AN/FSQ-7 (XD-1). There was no dissection and analysis of retired tubes. The IBM-Kingston Display Tube Group agreed to do this work, but did not initiate their program this quarter. The Hughes production facilities continued at a fraction of rated capacity while Machlett Laboratories, under contract with Hughes, continued its effort to qualify as second source for the digital display tube. Machlett has set up its equipment and facilities and has obtained most of the necessary jigs and fixtures. Next quarter Machlett will make three prototype qualifying tubes and start an initial production of 25 tubes.

Group 65 continued on its life-test racks 17 early production tubes to evaluate the potential life of the two cathodes in each tube. Tubes were continued on life even when they failed other tests if the cathodes were satisfactory. Five of the 17 tubes continued to meet all of IBM purchase acceptance test specifications and would be operable in a display console. Three tubes had writing gun currents that were becoming marginal, and two flood guns had marginal currents. The distribution of Typotron operating hours on life test is:

| Number of Tubes | Number of Hours |
|---|---|
| 10 | 13,000 – 14,000 |
| 2 | 18,000 – 19,000 |
| 5 | 19,000 – 20,000 |

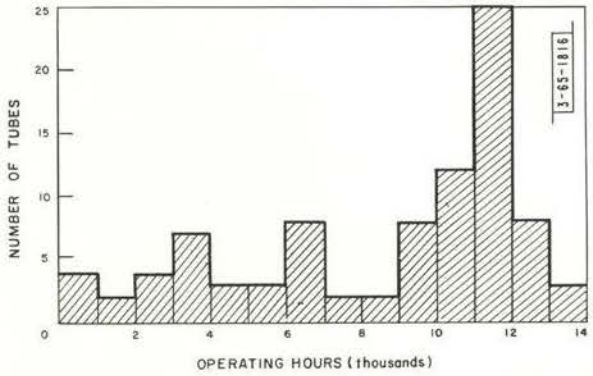


Fig. 65-4. Distribution of Typotron operating hours in AN/FSQ-7 (XD-1), (XD-2), and consoles being tested by IBM.

The 94 Typotrons in XD-1 had accumulated an average filament-hour life of 8610 hours as of 1 September 1957 compared with 8872 hours as of 1 June 1957 (Fig. 65-4). Six Typotrons were removed this quarter from AN/FSQ-7 (XD-1) with no removals due to gassiness. This removal rate is one-half that of any of the three previous quarters, possibly because this improvement may reflect the benefit of the additional impedance in the $A_3$ supply which was installed December 1956 to minimize intense arcing between $A_3$ and the storage assembly. The failure results are summarized below:

| Life-Test Hours Before Failure | | Reason for Removal |
|---|---|---|
| Filament Hours | d-c hours | |
| 1807 | 1323 | Leakage between collector mesh and storage mesh |
| 2808 | 2689 | Poor storage |
| 9516 | 5321 | Low write-gun emission |
| 9788 | 8962 | No write-gun emission |
| 12110 | 10424 | Collector mesh goes positive |
| 14048 | 10990 | Collector mesh goes positive |

Fig. 65-5. Causes of failure in Typotrons removed from AN/FSQ-7 (XD-1) June – September 1957.

In Fig. 65-6 the average hours of Typotrons removed from AN/FSQ-7 (XD-1) are tabulated by quarters.

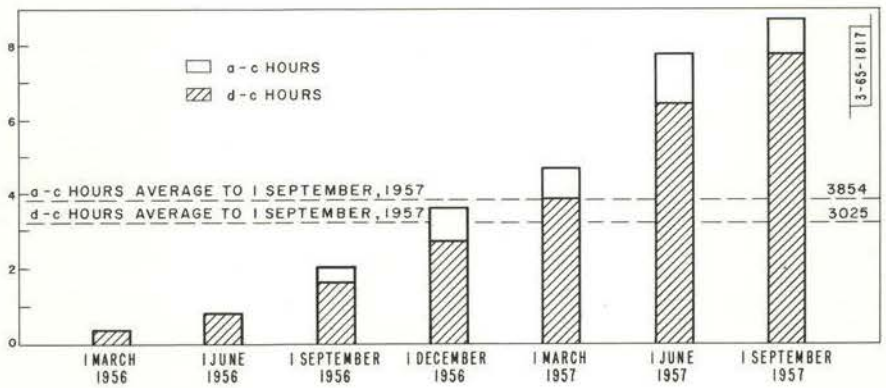


Fig. 65-6. Average hours of Typotrons removed from AN/FSQ-7 (XD-1) during 1956 and 1957.

The sites have not released any detailed operational data on the Typotrons. The display consoles at both DC-1 and DC-2 have been retrofitted with additional $A_3$ impedance to reduce the incidence of gassiness in Typotrons. The retest at Kingston of 24 Typotrons removed from DC-2 this quarter showed that 5 tubes met initial test specifications and 19 were rejects. These tubes had operated an indeterminate number of hours before consoles were modified. Most of the rejects fell into two categories:

(1) No flood gun current but satisfactory writing gun. This is often caused by arcing between $A_3$ and storage assembly.

(2) Writing time longer than specifications.

## C. RECEIVER TUBE RESEARCH AND ENGINEERING

### 1. Low Power Twin Triode (6414/0528)

a. General Electric Company

No production data is available but General Electric is still unable to produce the high yield it had before the shutdown of last year. However, delivery schedules are being met. Incoming quality and life reports are good with all lots passing incoming inspection. An adequate inventory (enough for three systems) of 6414's is in stock at Kingston.

The 6414 specification is now awaiting Air Force approval.

b. Raytheon

Raytheon is producing at a yield of 50% and is now up to date on shipments to Kingston. Improved factory yield during the next quarter may increase its output above the 6000 tubes per month that IBM requires. Other potential customers are being canvassed to avert an inventory buildup with all of its consequences.

One factor which could prevent Raytheon's expanding production is a shortage of approved cathode melt. The cathode material vendor notified Raytheon that he is nearing the end of the approved A31 cathode melt supply that Raytheon has been using and no new melt is yet approved. Raytheon has one P50 melt available which was proved-in quite some time ago. It is hoped that this will last until a new melt can be approved.

### 2. Dual-Control Gate Pentode (Type 6888/SR-1782A)

a. Sylvania Electric Products Incorporated

Sylvania produced the 6888 to good levels of quality in sufficient numbers to meet Kingston schedules. It is expected that the factory will have gained sufficient experience with the design change in the pulse plate current specification to permit establishing a mutually satisfactory revised specification during the next quarter. The pulse-plate current specification is scheduled to be resolved during the next quarter. It is expected that the factory should have run enough lots and gained sufficient experience with the design change, reported in the last quarterly, for an evaluation of all its implications. These factors should permit the establishment of a mutually satisfactory and realistic pulse-plate current specification.

b. Bendix Aviation Corporation – Second Source

Bendix is producing the dual-control gate pentode to acceptable quality levels. Capacity exceeds demand due to the stretch-out of the machine delivery schedule. Life-test reports on Bendix tubes are satisfactory. Bendix has tooled up and is producing samples of the aligned grid design* (referred to in the 15 June 1957 Quarterly Progress Report) and these should be received early in the quarter for an engineering evaluation.

### 3. High-Power Twin Triode

a. Tung-Sol

Tung-Sol stopped production of the 5998 because production exceeded demand. Kingston has an inventory sufficient for several machines and Tung-Sol has up to 25,000 from the overrun. Tung-Sol has announced that in the future 5998's will be made by Chatham, now a wholly owned division, unless Chatham is unable to produce a satisfactory product. Tooling and parts for several months production are being held by Tung-Sol against this possibility. Thus there is no second source on the high-power twin triode. The personnel whose skills are an important factor in the quality of the type were transferred to other tasks and thus will have lost some of their artfulness should a return to production be necessary.

b. Chatham Electronics Division of Tung-Sol Corporation

Chatham Electronics Division of Tung-Sol Corporation is now the manufacturing source for the high-power twin triode.

This simple triode is difficult to make because of its close inter-electrode spacing and relatively long cathode-grid structure. Chatham has apparently solved the problem of cathode coating adherence but is now experiencing grid trouble. The grid lateral wires puff out (increasing the minor outside diameter) during life on the IBM racks, although Chatham reports no difficulty of this type in its own life tests. Chatham is employing a grid design which features side-rods approximately the same dimension as the minor diameter of the grid. Common practice is to construct the grid with siderods smaller than the minor diameter of the grid. Normally, the minor diameter is controlled by the tooling of the grid machine and subsequent shaping operations. The Chatham design permits only small changes by these methods. Life-test studies have begun at Chatham and at the Kingston Military Products Division, but the quality of the Chatham product has not yet been proven. Chatham's progress will be monitored to make sure that they will be producing quality tubes before the Tung-Sol inventory is depleted.

### 4. AN/FSQ-7 (XD-1) Receiver Tube Removals

The total number of operating hours of these tubes is not available. The major cause for removal was low or no output, except that the number of microphonic/noisy 5965's increased to nearly half of the total removals – double the number reported for the previous quarter.

Figure 65-7 gives the failures and percentages of AN/FSQ-7 (XD-1) tubes with the four critical types listed first.

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* Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 June 1957) Section V.C.2.b.

| Tube Type | No. of Failures | Percentage of Failures to Total XD-1 Tube-Type Complement (Total based on Report #060311 IBM – 27 March 1957) |
|---|---|---|
| 6414 (Z-2177) (11 opens, 5 shorts, 4 microphonics/noisy) | 50 | 0.6 |
| 5965 (3 opens, 82 shorts, 15 intermittents, and 286 microphonics/noisy) | 679 | 11.0 |
| 2420 (6888) (1 short) | 241 | 2.8 |
| 5998 (2 intermittents) | 43 | 2.6 |
| 6146 | 1 | 0.5 |
| 6161 | 33 | 12.2* |
| 5727 | 13 | 2.0 |
| 5783 | 12 | 3.0 |
| 6577 | 1 | 0.9 |
| 6072 | 4 | 0.8 |
| 5881 | 4 | no data |
| 6136 | 1 | 0.2 |
| 5718 | 1 | 1.0 |
| * Note: nearly as high as last quarter. | | |

Fig. 65-7. Summary of failures of receiver type tubes in AN/FSQ-7 (XD-1).

### 5. Deflection Driver

a. 6161

During this quarter the 6161 deflection driver had the highest failure rate of any tube in AN/FSQ-7 (XD-1) and a high rejection rate at incoming inspection and test at Hazeltine Electronics Corporation where the display consoles are made. Most of the rejects from AN/FSQ-7 (XD-1) were short circuits and poor filaments, caused by particles and tilting of the cathodes. The manufacturer, RCA, has taken extra cleanliness precautions to minimize the particle problem. The cathode tilting, caused by incomplete brazing of the inverted can type cathode, resulted in unequal heating of this electrode and consequent differential expansion. Process changes and strict inspection procedures are expected to reduce greatly the frequency of these defects. An RCA-Kingston correlation difficulty on short circuit tests was resolved by RCA and Hazeltine adopting the more sensitive procedure.

## D. RESEARCH

### 1. Matrix Studies

A series of 19-inch Charactrons was started and one completed this quarter so that Group 63 could evaluate new models of Gurley matrices for the situation display.

### 2. Phosphor Studies

One tube was designed and made for Group 62 to develop a comparison light photometer for Charactron brightness measurements.

Transparent phosphors may improve character resolution for display systems. Two cathode-ray tubes were constructed to evaluate this type of phosphor as:

(a) A single phosphor,
(b) Aluminized,
(c) Coated with P11,
(d) Aluminized and coated with P11.

These tubes permit a direct comparison of contrast, brightness, and other display tube factors; initial evaluation tests by Group 63 were encouraging.

### 3. Ferroelectric Switching Studies

Two barium-titanate crystals were prepared with multiple electrode leads to permit Group 63 to measure the switching and hysteresis properties. Three electron beam tubes with a matrix of cages as targets were prepared as electron beam switching tubes for the barium titanate switching studies. This type of tube could also be used for the switching of cells in electroluminescent panels. These studies are under evaluation by Group 63.

### 4. Solid-State Displays

An evaluation was begun of persistent solid-state display panels under direct-beam bombardment inside cathode-ray tubes. Initial results showed that there is no apparent incompatibility between panels and tubes. For the continuing study, Group 65 will make its own panels.

The first series of experiments to prepare electroluminescent panels with the phosphor embedded in an organic binder was successful. Panels constructed with this type of layer are more compatible for application outside a vacuum tube. A process specification will be prepared after further experiments.

A program to make glass-embedded electroluminescent layers was continued for vacuum-tube applications. A glass powder is being sought which will carry the phosphor undisturbed during the sintering of the powder to the conductive glass substrate. When photoconductor and electroluminescent techniques are developed for vacuum-tube operation, these layers will be formed directly on the face of a cathode-ray tube (e.g., the Charactron tube). Test equipment similar to that of Group 24 was set up in Barta Building to evaluate the progress of the electroluminescent layer experiments. Experiments were conducted to lay a photoconductor mosaic on the electroluminescent layer so that the two could be isolated optically.

P. Youtz J.S. Palermo
T.F. Clough

SAGE DC AND CC SITES

GROUP 66

MORRISS, B. E., *Leader*

McVICAR, K. E., *Associate Leader*

BRAGAR, P.
BROCK, L. T.
CALLAHAN, T. R.
CROKE, J. J.
HEDISON, H. H.
HOLDEN, W. E.
IPPOLITO, V. O.
LINEHAN, L. H.
MANNING, F. F.
MAYER, R. P.
ROBERTS, A. J.
SERGIO, L. S.
SHOREY, R. R.
THOMPSON, S. L.

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# VI. SAGE DC AND CC SITES
## GROUP 66

## A. SUMMARY

At Lexington, improved program checkout procedures were put into effect; air defense computer programs were adapted for direction centers at McGuire, Stewart, Syracuse, and Fort Lee; three computer programs were begun which will perform 75% of the adaptation process now being done by programmers. At McGuire, Package D of the direction center active (DCA) program was 95% checked out and its delivery to Western Electric planned for 13 September; checkout of the direction center standby (DCS) program and the duplex switchover portions of the DCA program proceeded satisfactorily. At Stewart, the initial version of the DCA program was tested with no major discrepancies found. Test teams for both the direction and combat centers arrived at Syracuse and began installing utility programs.

B. E. Morriss
K. E. McVicar

## B. LEXINGTON

The contents and processing requirements of the first complete DCA program to be delivered by the RAND Program Development Group (PDG Model 0) were published in the following documents:

(1) 6M-4508, "PDG Model 0 Material to be delivered from Group 66 and PDG to Group 67," 6 August 1957

(2) 6M-4522, "Model 0 Materials from Technical Services Group to Group 66," 12 August 1957

(3) 6M-2513, "Model 0 Processing by Group 66" (to be published)

(4) RAND Memo #LM-3083, "PDG Model 0 Materials to be Delivered from Program Development Group to Group 66," 24 July 1957

The above memorandums reflect the development of improved scheduling, coordination, and checkout procedures developed during the quarter.

### 1. Program Control

A program control subsection was organized and procedures developed to insure that site reported program errors would be evaluated for accuracy and corrected at all field sites, and in addition would be corrected in future program development releases. These procedures are expected to shorten the interval between the receipt of a site team report and the delivery of a correction. During this quarter, eight error reports summarized approximately 270 completed discrepancy reports from McGuire and Stewart. The discrepancies fall into the following categories:

(a) Adaptation, modification, and internal group processing (115),

(b) Logic errors, specification errors, ambiguities in either logic or specifications (145),

(c) Suggested improvements (10).



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### 2. Test Planning

Recommendations for improved checkout were defined with these major points stressed:

(a) Program adaptation and testing should be concentrated on the geographic differences between sites.

(b) Program errors introduced by Group 66 processing should be singled out during tests.

(c) Machine-program compatibility should be determined in the tests.

Following the above recommendations, a series of simulated tests for the air surveillance portion of the DCA program has been produced for use at future sites, and plans have been made to produce such a test series for the balance of the DCA program.

### 3. Program Modification and Adaptation

Before being sent to Kingston, the DCA program packages are adapted to each site. Adaptation consists of inserting parameters defining the unique physical and geographical characteristics of the given sector. Program packages for the following sites were adapted during this quarter: McGuire, 15 July; Syracuse, 31 July; Stewart, 15 August; Fort Lee, 19 August. Three computer programs are being written to perform 75% of the computation, such as coordinate conversion for the adaptation process (about 2000 parameters), now done manually by programmers. The programs will be operated on the AN/FSQ-7 at Santa Monica.

Reduced processing time and more accurate program adaptation information are expected from the following changes: (1) machine modifications, incorporated in the master programs, which will enable the program to run on either XD-1 or a production AN/FSQ-7; and (2) the relocation of adaptation information in each program. The first modification will permit all program changes in ESS and SAGE sites to be discussed with reference to a single program, greatly reducing the effort and time required to prepare a program for delivery to each site. The second modification makes unnecessary the recompilation of the program with adaptation parameters for each site when the length of the program is subsequently changed. Plans have been made to equip the next model of the DCA program (Model 0) with two special programs to complete each site adaptation in a single continuous process; i.e., one turn at the computer will take all symbolic parameters, convert them to binary, and insert them in all adapted programs.

### 4. Transfer of Group 66 Responsibilities to RAND

Group 66 responsibility for installing and checking out the air defense computer program at SAGE sites is to be transferred to the implementation group of the RAND System Development Division. The change is scheduled to take place in October and November 1957. At this time most of the RAND personnel in Lexington attached to Group 66 will move to Santa Monica and the program implementation activity will work out of that headquarters. RAND personnel have been selected to replace each of the key Lincoln members.

P. Bragar
V.O. Ippolito
L.H. Linehan
R.P. Mayer
L.S. Sergio



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## C. McGUIRE

The checkout of Package D of the DCA program was about 95% completed by the end of the quarter and its delivery to Western Electric was planned for 13 September. The summary of the final test is contained in 6M-5189, "McGuire Test Plan Summary—D Package" dated 23 August 1957.

The checkout of the direction center standby (DCS) program and the duplex switchover portions of the DCA program proceeded satisfactorily during the quarter. Data was successfully transferred from the active to the standby computer under conditions simulating an emergency switchover. The DCS program in the inactive computer wrote onto its own intercommunication (IC) drum field the information which the safe data storage routine of the DCA program had written onto the active IC drum fields. Upon switchover, this data was transferred over to the proper drums on the standby computer and then printed out to permit a comparison with the data contained on the simulation deck printout of the active computer. A number of minor errors and inconsistencies in the DCS program were corrected without difficulty by Lincoln and IBM programmers at McGuire.

A final revised version of Package B was turned over to the Western Electric Systems test team on 8 August; several deficiencies discovered at McGuire or in ESS had been corrected.

T. R. Callahan
H. H. Hedison
W. E. Holden
A. J. Roberts
R. R. Shorey
A. R. Shortell
S. L. Thompson

## D. KINGSTON

The test facility teams for the Syracuse and Fort Lee Direction Centers and the Syracuse Combat Center were formed. The air surveillance and weapons direction portions of the DCA package were processed for release. Computer time was used by Group 66 in the following proportions:

| | |
|---|---|
| Training | 250 hours |
| Assembly tests | 150 hours |
| Package processing | 200 hours |
| Utility and instrumentation | 150 hours |
| Program checkout support | 50 hours |
| | 800 hours |

Fifty-five future members of test facility teams completed the utility and instrumentation program training course. The course consists of eight weeks of intensified program and computer training where the practical aspects of trouble shooting and test situations are emphasized. Syracuse and Fort Lee Direction Center teams left for their respective sites late in August, as did the Syracuse Combat Center team. The Santa Monica and Topsham teams began to take form during the period.

The updating of the D Package release for McGuire and Stewart was continued.

L. T. Brock
J. J. Croke
F. F. Manning



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Fig. 66-1. Stewart Direction Center. Stewart Air Force Base, Newburgh, N.Y., is the location of the direction center for the Boston Sector, one of 29 in the country. The main building contains the data processing, communications, and maintenance facilities. The smaller buildings in the rear contain diesel-driven power generation equipment (left) and air conditioning equipment (right).

Fig. 66-2. Syracuse Combined Site. The Syracuse DC-CC is a SAGE Division control point, of which there will be seven in the country. The building on the right is the combat center.



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## E. STEWART

The initial version of the DCA program, including the air surveillance and weapons direction portions, was tested before the end of the quarter. No major discrepancies were found; some minor errors still persist, however. These errors will be resolved during the testing of the D2 version of the program which started on 21 August. A successful test was run using live data from one long-range radar: initiation, correlation, and identification were performed on the data and a weapons assignment display on the tracks was called up.

## F. SYRACUSE

The test facility operation sections of both the direction center and combat center teams completed assembly of program and installation material at Kingston and moved to Syracuse in the middle of August. Installation of the utility system of programs was started on the AN/FSQ-7 on August 26. Installation of the program in the AN/FSQ-8 was expected to start late in September; until then the team will be provided with time on the AN/FSQ-7 for checkout of their programs. The test plans and analysis sections of both teams arrived on site and started the planning of tests and generation of assembly tests.



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## ADVANCE SAGE PROGRAM DEVELOPMENT

## GROUP 67

ZRAKET, C. A., *Leader*

ARDEN, MARGUERITE
AXELROD, E.
BACHELDOR, L.
BAGLEY, P. E.
BAILEY, D. L.
BENSLEY, E. H.
BRISCOE, H. W.
BUDD, ELEANOR
BURROWS, J. H.
BYRNE, W. P.
CHANDLER, A. R.
CLAPP, ELIZABETH
COLLINS, L. B.
COYNE, J. D.
EARL, D.
FERGUSON, MARY
FRACHTMAN, H. E.
GOCHMAN, H.
HAGER, L. S.
HALPERN, BARBARA
HILLS, MERITHEW
JONES, K. L.
KIRSHNER, H. J.
LATIMER, D. P.
LUNDBERG, E. D.
MARKE, J. T.
MARNIE, G.
MEAD, W.
MILBERT, A.
MILLER, J. F.
NEWHALL,H., JR.
ORNSTEIN, S.
PATTON, R. L.
PORT, S. C.
RISING, H. K.
STONE, J. H.
STRAIT, PEGGY
THOMAS, L. M.
VANCE, P. R.
WILSON, L. D.
YNTEMA, MARY

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# VII. ADVANCE SAGE PROGRAM DEVELOPMENT
# GROUP 67

## A. SUMMARY

On 1 June 1957 Package D of the direction center active (DCA) program was delivered to Group 64 for ESS shakedown and to Group 66 for adaptation to SAGE sites. The responsibility for the production, maintenance, and error correction of all future SAGE DCA programs was assumed by the RAND Program Development Group. Group 67 continued to operate the program for ESS shakedown.

Thus relieved of DCA program production and maintenance, the group directed its attention to developing programs for testing new air defense functions before their inclusion in SAGE. A specification was written for non-operational testing of the crosstelling function in ESS. Modifications to the ESS intercept program were begun, the principal one making automatic the change of tactics to "final-turn" from "cut-off." The track-while-scan portion of the SAGE Non-Real-Time (SNORT) simulation was begun.

A study of the DCA program operation time yielded measurements which indicated that frame time (the sum of subprogram operating times and control time – nominally 15.7 seconds) will not limit the initial SAGE system capacity. The details of Mode II (adjacent sector disabled) capability were worked out in cooperation with Air Defense Command. In taking over a disabled sector, a normal sector in Mode II will lose some defense capability in the form of capacity per unit area, but the character of the defense will not change. In July, the group assisted Air Defense Command in the redeployment of SAGE boundaries in the western United States.

A system of data processing programs called TADOR (table design data organization and reduction) was completed which maintains and prints out up-to-date DCA program table design information more rapidly and accurately than the manual system formerly used.

C. A. Zraket

## B. ESS SUPPORT

On 1 June 1957 Package D of the DCA program was turned over to Group 64 for ESS shakedown and to Group 66 for adaptation to SAGE sites. During the quarter all RAND personnel in Group 67 were released to the RAND Program Development Group (RPDG), taking with them the responsibility for the production, maintenance, and error correction of all future SAGE DCA programs. Group 67 continued to operate the program for ESS shakedown. Memorandum 6M-5175, "Contents of the Final D Package Released by Group 67 on 1 August 1957 and Related Documentation," was published on 14 August 1957.

### 1. Crosstell Test Facility

A specification was written to test the crosstelling function in ESS. Since there is no method in ESS of operationally testing this function without tying ESS to another operating sector, ESS was divided into two geographical units and the DCA program was correspondingly divided into two logical programs. Half of the consoles in the direction center were designated as the prime



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sender, the other half as prime receiver. The specifications are contained in 6M-5186, "Design Specifications for a Proposed Test Facility for the Crosstell Function in ESS."

### 2. Intercept Direction Studies

In cooperation with RPDG, Group 67 removed a number of errors in the intercept direction portion of the DCA program. Program modifications were begun as proposed by Group 66 in 6M-4503, "Modification to ESS Intercept Program." The principal modification makes automatic the change of tactics to "cutoff" from "final turn" when a specified time and distance to the offset point are reached. The logic avoids situations where flight path configurations cause continual shifting of the offset point and result in delay in execution of the final turn. The logic also allows the continual vectoring of an interceptor in a final turn.

## C. PROGRAM DEVELOPMENT AND SUPPORT

### 1. Track-While-Scan Simulation Program

The specifications for the track-while-scan (TWS) portion of the SNORT (SAGE Non-Real-Time) simulation were received from Group 61, and the writing of the program was begun.* TWS is designed to simulate SAGE tracking on an IBM-704 computer. The program will be used to evaluate the present tracking logic of SAGE using different sets of parameters (e.g., smoothing constants, search area sizes). Later different logic approaches will be evaluated. The TWS program will also prepare a "target track" input tape for use with the various portions of the weapons guidance and tracking programs of SNORT, and will be used to evaluate SAGE guidance logic for such weapons as BOMARC. It will have a capacity of 175 tracks. Simulated radar data from four LRI sites will be fed into the program; TWS will then perform the following functions:

(a) Radar data conversion and transport formation,
(b) Establishment of initial pickup tracks and subsequent correlation,
(c) Correlation of radar data with tracks,
(d) Smoothing and prediction of track positions and velocities.

H. K. Rising

## D. A STUDY OF FRAME TIME IN THE SAGE DCA PROGRAM

With the virtual completion in late May of the first SAGE DCA program, the group began a study of DCA program operating time. Measurements were taken to study the capacity of the air defense system as determined in part by program operating time. These measurements will also support a study of the increase in system capacity possible in 1959 SAGE in which operational requirements will be increased in the weapons control function, and system capacity will be augmented by the 65,000-register core memory and improved programming techniques.

Three types of measurements were taken:

(1) Total program frame time as a function of system load,
(2) Individual subprogram operating time,
(3) Control time (i.e., in-out time and sequence control subprogram operating time).

* See also Section I, C, 1 of this report.

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As a measure of system capacity, the first item, frame time, is the most significant. Frame time is the sum of the operating times of the individual subprograms and the control time – 15.7 seconds in the DCA program. Under light load conditions the program operating time is less than the frame time and the program marks time waiting for the full frame to elapse (six display cycles at ±2.62 sec. per cycle). Under severe load conditions, the program operating time, and hence the frame time, may exceed 15.7 seconds: some functions of the system will be delayed and others cut off. A switch insertion delay, for example, will be longer in direct proportion to the increased frame time, while radar returns in excess of input capacity will be rejected. If program calculations are not completed by the end of the frame, they continue until they are completed. Because it is designed to accommodate overtime operation, the system exhibits a gradual, rather than an abrupt degradation as frame time is increased beyond the nominal 15.7 second figure: most of the degradation is in the form of delayed system response.

Although an exact model of system load for measurement purposes is difficult to assume, the following conditions were considered appropriate for this study:

(1) 100 tracks,

(2) 60 tracks using radar data (the remainder were crosstold tracks, manual input tracks, etc.),

(3) 45 interceptors for which vectoring computations were being made. (22 of these were interceptors with final turn tactics, 23 with cut-off tactics),

(4) 1200 radar returns.

The results of the study can be summarized by a frame time equation:

$$F = 9.80 + .041\,N + .063\,I + .0014\,R$$

where F is the frame time in seconds, N is the number of non-interceptor tracks, I is the number of simultaneous interceptions, and R is the number of pieces of radar data per frame. The effect on F as N, I, and R are varied is shown graphically in Figure 67-1(a-d).

It is the conclusion of the group that a frame time of 18 seconds would not significantly degrade SAGE system capabilities, and would accommodate the full-load frame time of 16.7 seconds as shown in Figure 67-1, plus the estimated 1/2- to 1-sec additional time which will be added by the forward-and crosstelling functions. Thus, program operating time will not limit the initial system capacity. Furthermore, the portion of program operating time attributable to in-out time – about 7 seconds – will be reduced to about 1 to 1.5 seconds with the addition of the 65,000-register core memory.

Detailed results of the tests described above will be published in 6M-5265, "Measured Frame Time for the SAGE DCA Program (Package D)," by D. L. Bailey.

## E. EMERGENCY CAPABILITY – MODE II

Group 67 and Air Defense Command have jointly worked out details of Mode II, an emergency facility to be available as part of the SAGE system in 1959.* Mode II is called for by the division commander and/or the sector commander if a SAGE direction center becomes disabled. Direction

* To be published in 6M-5264, "Operational Specifications for Emergency Capability (Mode II) in the SAGE System."



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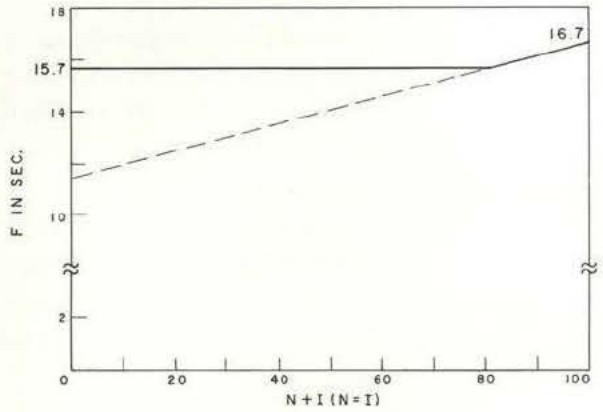
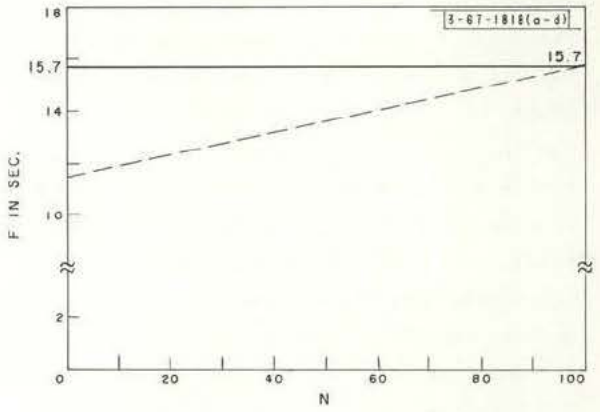
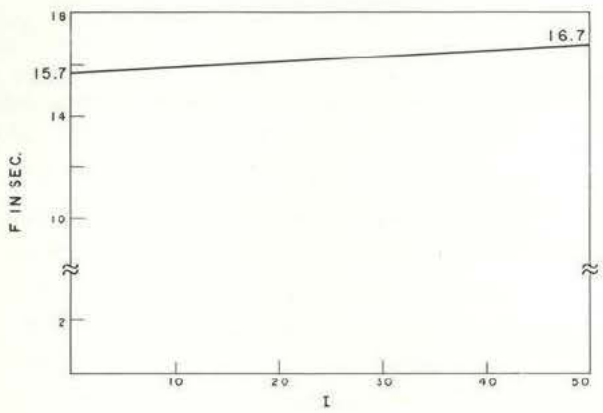


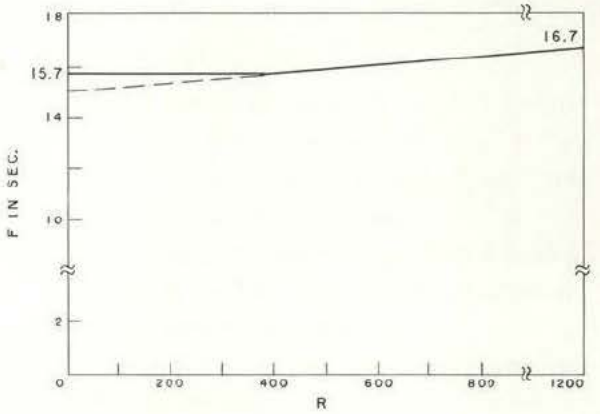

(a) Frame time (F) as a function of an equal number of non-interceptor tracks (N) and simultaneous interceptions (I) in the system. 1200 pieces of radar data per frame are assumed. The maximum frame time of 16.7 seconds represents approximately a full combat load condition.




(b) Frame time as a function of non-interceptor tracks, with 1200 pieces of radar data. This condition represents the surveillance and detection capacity of the system (pre-combat).




(c) Frame time as a function of an increasing number of interceptions, assuming a constant 100-track load (i.e., I = 100 – N; N = 100, 99. . . , 50). This curve represents the transitional period between surveillance and combat status.




(d) Frame time as a function of pieces of radar data (R), with 50 interceptor tracks and 50 non-interceptor tracks. The area between the solid and dotted lines in this and the other figures represents time buffering in the program (see text).

Fig. 67-1(a-d). Frame time as a function of system parameters.



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centers in adjacent SAGE sectors will accept full air defense responsibility and authority over specified portions of the disabled sector.*

The computer programs in each sector will be designed to accommodate expansion of their surveillance and weapons control functions to cover the disabled area.

### 1. Data Processing

When a sector goes from Mode I (normal) to Mode II operation, increased demand is placed upon the processes carried out by the program and on the data storing capacity of the system. Mode II has been designed to introduce extra program requirements, therefore, only when they bring about an appreciable increase in Mode II system capabilities. No attempt is made to match Mode I capabilities point for point, but only where the results justify the increased demands upon the program.

To minimize data storage requirements, four rules have been introduced:

(a) A sector will be capable of Mode II expansion into no more than two adjacent sectors.

(b) A sector will be able to assume Mode II control of only one other sector at a time.

(c) Only one expand zone or area will be defined in each of the two adjacent sectors.

(d) Responsibility for a disabled sector will be shared by at most two other SAGE sectors (which need not be in the same Air Division). The burden of Mode II operation is thus placed on as few sectors as possible, thereby increasing the number of Mode II situations which the entire SAGE system can simultaneously handle.

### 2. Displays, Radar Coverage, and Communications

Neither the display scale nor the area covered will be altered as a result of Mode II expansion. The same normal and contracted displays will serve both normal and emergency modes. The facilities (e.g., search radars, G/A communications) of the normal sector will remain unaffected. Some computing capacity will be used to control the disabled area: the loss of capability in the normal sector is one of capacity per unit area, and not in the character of the defense. In the disabled area, however, there is significant difference in defense capability:

(a) Full BOMARC control capability is maintained, with some degradation in surveillance capability due to the absence of gap fillers and triple long range coverage.

(b) ADC manned interceptor bases will remain under SAGE control, as will a number of the augmentation bases.

(c) Low altitude G/A data link communications will be lost in a good part of the zone; G/A voice communications will suffer to a lesser extent.

(d) Adequate high altitude search radar coverage will be available due to the already existent cross-tie of long range radar sites.

(e) Gap filler coverage will be lost.

(f) Height finder data will be available from sites only semiautomatically, not by voice phone.

(g) Crosstelling will not be selected automatically when the selection is due to track position.

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* See also Section I, D, 1 of this report.

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A large portion of the Mode II facilities required will be incorporated into the DCA program. Mode II air base data, for example, will be available at all times to the computer program and to direction center personnel, but will be used only under standard Mode II procedure. The remainder of the changes required for Mode II operation – primarily boundary radar and masking parameters – will be stored on the auxiliary drums as completely independent parameters. These will replace Mode I parameters when the air surveillance officer takes the keyboard action "EXPAND – SECTOR X."

To determine the success of this specification for Mode II operation, Group 67 will examine in detail its application to the first operational SAGE division, the 26th Air Division. The results will be reported with a specification for adaptation requirements in that division.

## F. SAGE DEVELOPMENT STUDY

In July, members of the group participated in an Air Defense Command review of SAGE deployment in the U.S. and Canada. A detailed review of each sector was made to insure that the resulting deployment of boundaries, radars, weapons, etc., was compatible with the planned SAGE capability in 1960. A report of the study, "SAGE Deployment Review," was issued by Air Defense Command on 3 August.

## G. DCA AUTOMATIC DOCUMENTATION PROGRAM: TADOR

A system of data processing programs has been written for the AN/FSQ-7 (XD-1) computer which maintains and prints out up-to-date DCA program table design information. The composite program is called TADOR – table design data organization and reduction – and contains 17 programs totaling approximately 14,000 instructions.* A complete description of the organization and operating procedures of TADOR has been published in 6M-4477, "Table Design Data Organization and Reduction (TADOR) Sections 1, 2, and 3," dated 24 July 1957.

TADOR is operated in a weekly routine as follows:

(1) The master tape, containing all TADOR programs, is read into the computer and stored on the drum. From this point on, all component programs are operated by mnemonic control card under control of the TADOR control program.

(2) The tapes containing the design files and the current week's changes are combined to produce a new design file tape.

(3) The new design file tape data is stored on the drum.

(4) Each of the TADOR listing programs and the compool generation program are operated. These programs take design data from the drum, assemble it into the proper form, and put it on tape for off-line printing or, in the case of the compool, for use by other computer program systems.

During a typical weekly production run of about one hour on AN/FSQ-7 (XD-1), the system processes from tape input the equivalent of 10,000 IBM punched cards to produce on tape for off-line printing the equivalent of 450 pages of published material. The previously used manual system of coordinating program changes required at least 35 hours per week and was more subject to error.

* Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 June 1957), Section VII, C, 2.

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SYSTEM OFFICE

GROUP 68

BROWN, D. R., *Leader*

BOYD, H. W.
COLLINS, L. B.
GINSBURG, S. B.
GIORDANO, J.
MAY, J. P.
OGDEN, W., JR.
PARKINS, T. R.
RUPP, A.
VANCE, P. R.

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# VIII. SYSTEM OFFICE
## GROUP 68

## A. SUMMARY

The System Office is responsible for gathering and coordinating all available information regarding changes that are proposed to the computer programs, equipment, or operating procedures of SAGE direction or combat centers. Some 200 changes have been or are now being evaluated. Among them are those required for the 1959 SAGE DCA Program; installation of BOMARC frequency-division data link (FDDL) and time-division data link (TDDL) output sections for AN/FSQ-7's and DCA program changes for FDDL compatibility in ESS.

D. R. Brown

## B. SYSTEM OFFICE ACTIVITY

Some 200 evaluation requests have been made of the System Office, each of which has been started through the following procedure:

1. The agencies likely to be interested are asked to furnish data on which the System Office can base a preliminary evaluation of the expected gain and cost of the proposed change.
2. On the basis of the preliminary evaluation one or more of the following steps are taken:
   (a) All specifications, cost estimates, schedules, etc., that pertain to the change are obtained,
      (1) RAND, in the case of program changes, is requested to determine the number of programmer man-hours and computer hours, the amount of storage that will be required, and the effect on frame time.
      (2) IBM, in the case of equipment changes, is requested to supply detailed equipment specifications, determine the schedule for the design, manufacture, installation, and test of the equipment, and determine the schedule for making the change.
   (b) The request is filed for future action until progress of the SAGE System or some part of it yields more specific information.
   (c) The request is withdrawn.
3. The System Office reviews the specifications, schedules, costs, etc., and verifies compatibility of related program and equipment changes.
4. The System Office writes a recommendation which,
   (a) Describes the change,
   (b) States the gain expected as a result of the change (the increase in air defense capability),
   (c) Outlines the cost of the change,
   (d) Recommends actions to be taken by IBM, RAND, or others.

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5. The recommendation is circulated for concurrence signature to
   (a) The designers of the change to certify that the recommendation accurately describes the change and the expected gain,
   (b) The organizations who will carry out the change to certify that the cost and schedule information is accurate, and
   (c) The users of the change to certify that the statement of gain is accurate and that the change is justified.
6. The recommendation is formally released by Technical Information Release.

## C. 1959 REVISED PROGRAM

Implementation of the 1959 SAGE revision will be evolved as a series of steps based on established or estimated schedules for the availability of the new features.

The DCA program will be revised in a series of successive "models" which will be written by the RAND Program Development Group to include the new features as they become available. By September of 1959, the DCA program will take advantage of the increased capacity that will be afforded in the computer system by the addition of the new 256 × 256 × 38 (2.5 million bits) core memory. The following nine major features and the equipment and program changes related to them are being studied and evaluated for integration into 1959 SAGE:

(1) BOMARC
(2) Nike
(3) Century-Series Manned Interceptors
(4) SIF Tracking
(5) Time-Division Data Link (TDDL)
(6) Automatic Weapon Assignment
(7) Emergency Capability
(8) SAGE System Training Program (SSTP)
(9) Increased Track Capacity

The dates when these new features will become available in the field have not yet been established, except in the case of BOMARC. However, designs have progressed sufficiently on all of them to warrant initial studies regarding their integration.

## D. DATA LINK OUTPUT SECTIONS

System Office Recommendation, 6M-4460,* was released by TIR-1-200, and covered the AN/FSQ-7 and AN/FSQ-7 (XD-1) output sections needed to control BOMARC's equipped with frequency-division data link (FDDL) and both BOMARC's and manned interceptors equipped with time-division data link (TDDL). Members of WE-ADES, ADES Project Office, IBM, RAND Program Development Group, Lincoln Project Office and Lincoln Groups 68 and 62 contributed to the recommendation which was based upon the following two documents issued by ADC:

* H.W. Boyd for the System Office, "The Addition of BOMARC Frequency-Division Output Sections and Time-Division Output Sections to AN/FSQ-7's." M.I.T.-Lincoln Laboratory Report 6M-4460 (1 July 1957).

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(1) "Employment of BOMARC IM-99 in the SAGE Era," Revision 1, dated 21 February 1957, which states that additional AN/FSQ-7 frequency-division data link output sections are to be procured for BOMARC control.

(2) "Operational Plan for Time-Division Data Link," dated 15 June 1957. The output sections required for SAGE to meet this operational plan will control both BOMARC's and manned interceptors that are equipped with a time-division data link.

### 1. BOMARC FDDL Output Sections

BOMARC missiles assigned to initial Air Defense Missile Bases (ADMB's) will be equipped with frequency-division data link (FDDL). Each ADMB will have 48 controllable missiles, the control of which will be divided between two direction centers. All direction centers will be capable of controlling the missiles at two ADMB's within its own sector and two ADMB's in adjacent sectors. Each direction center will probably need at least two duplexed FDDL output sections or as many as are required by the deployment of BOMARC (see Fig. 68-1).

The first operational ADMB is scheduled for McGuire AFB (New York Sector) in September 1959 and will use FDDL-equipped BOMARC's. Retrofits of the BOMARC FDDL output sections will be phased in with the schedule for the $256^2$ memory retrofits, beginning with the Gunter Direction Center (Montgomery ADS).

FDDL output sections for BOMARC's will not be provided at AN/FSQ-7 (XD-1), (XD-2), or the AN/FSQ-7's at Santa Monica and Grandview. One such output section will be provided at Gunter, where initial test firings of BOMARC's are scheduled for mid-1959 to further demonstrate SAGE-BOMARC compatibility.

### 2. TDDL Output Sections

Interceptors (manned and BOMARC) equipped with time-division data link (TDDL) will be integrated into SAGE beginning in 1961. Deployment schedules for TDDL-equipped BOMARC's at ADMB's are not yet available, but the installation of TDDL output sections will follow the same retrofit schedule as the FDDL output sections and the $256^2$ memory. TDDL output sections will be installed in both AN/FSQ-7 (XD-1) for component and system tests and AN/FSQ-7 (XD-2) for the BOMARC single-thread test firings. Santa Monica will not need a TDDL output section.

## E. DCA PROGRAM/FDDL COMPATIBILITY IN ESS

FDDL-equipped aircraft are already being used in live tests of the Experimental SAGE Sector (ESS). The System Office recommended in 6M-4453* that Group 67 modify the DCA (direction center active) program to provide command altitude over the ground-to-air data link for both the F86-L and the F-102A and to include the test message format supplied by Group 311.

Because many of the aircraft specified for use in SAGE will have program requirements different from those presently operating in ESS, a separate study and recommendation will be made of the program changes necessary to provide FDDL compatibility with the SAGE System.

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*E.S. Pulk (IBM) for the System Office, "Changes to the DCA Program to Provide Frequency-Division Data Link (FDDL) Compatibility," M.I.T.-Lincoln Laboratory Report 6M-4453 (25 June 1957).



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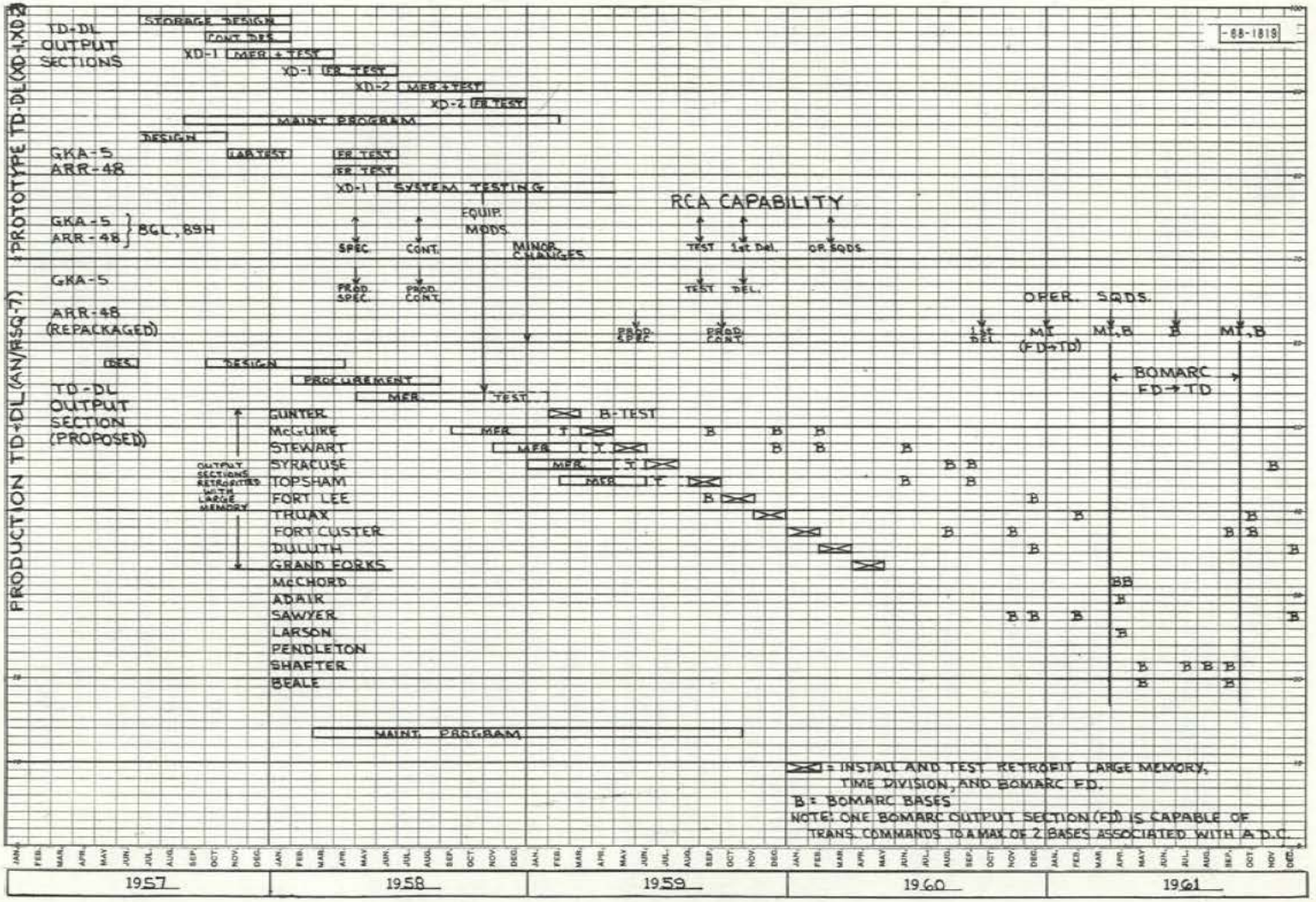


Fig. 68-1. AN/FSQ-7 output element modification proposal.



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## ADMINISTRATION AND SERVICES

## GROUP 60

PROCTOR, J. C., *Leader*
FALCIONE, A. M., *Associate Leader*

ARNOW, J. A.
ATTRIDGE, W. S., JR.
BIAGIOTTI, R. J.
ESSLER, G.
FALCIONE, A. M.
FERGUSON, M. M.
GROVER, C. S.
HAZEL, F. P.
HEIDLER, G. R.
HILL, A. P.
HODGDON, H. W.
JACOBS, J. F.
JOHNSON, F. B.
KATES, W. A.
LEVENSON, JUDITH
MILLER, R.
MORLEY, H. B.
SMITH, A. R.

# IX. ADMINISTRATION AND SERVICES
## GROUP 60

## A. SUMMARY

The main activity of Group 60 is of a supporting nature. The General Engineering Section furnishes design, fabrication, and assembly services to the division. It reports as noteworthy over a dozen pieces of specialized equipment, chiefly substrate holders, designed since the beginning of the year for Group 63 in support of their investigation of the physics of thin films evaporated under high vacuum. These substrate holders secure the glass plates upon which the metal film is deposited.

J.C. Proctor

## B. GENERAL ENGINEERING

Increasing interest and investigation into the physics of metallic films evaporated in a high vacuum has brought about a need for special apparatus to obtain reliable experimental data. Since early 1957, the General Engineering Section has designed more than a dozen such pieces of specialized laboratory equipment* in support of research being carried on by Group 63. The equipment will help Group 63 to acquire more knowledge of the physics of thin films for specific application to the design and construction of a computer memory considerably faster than today's high-speed core memories.

The rotating substrate holder permits identification of variations in the composition of an evaporated film with respect to the distance from the center of the substrate upon which it is to be deposited. The substrate is rotated at high speed to average out during deposition random differences in deposition pattern. Consistent variations will appear as concentric circles. A motor-driven, rotating substrate holder was in final drawing stage at the end of the quarter. One of the principal problems anticipated was the evaporation of the motor lubricant. To solve this problem the design specifies that the motor be completely enclosed in a stainless steel can, and that the torque be transmitted through the wall of the can by means of coupled magnets.

A multiple exposure substrate holder has been designed to make experiments more precise and to enable five days' work to be done in one. Five shutters, resembling trap doors, will be opened individually from outside the bell jar while deposition is taking place, progressively exposing one-fifth more of the substrate. There are two specific advantages in this method: (1) five varying thicknesses of film are obtained in one run with a proportionate saving of time; and (2) exact thickness ratios between samples from the same melt can be obtained, thus giving the experimenter exceptionally controlled conditions for investigating the effect of relative thickness on the physical properties of the films, as well as an indication of any variation in the composition of the vapor with respect to deposition time.

Other pieces of equipment in the design stage include a substrate holder furnished with permanent magnets for applying a 500-oersted field to the film during deposition, to permit evaluation of Ni-Fe alloys of any composition; a nitrogen-cooled substrate holder to study the

*See Lincoln Laboratory Quarterly Progress Report, 15 June 1957, Section IX, B.2.

effects of low temperature on the adherence of the film to the substrate; a reversible substrate holder to double the available evaporation surface and to study the possible variation of the beam with respect to time; and a nitrogen cooling coil for quenching a substrate after deposition.

The relatively easy interchange of all the apparatus mentioned here has been provided for by a basic structure permanently mounted inside the bell jar. Four posts support a horizontal plate upon which a desired substrate holder can be quickly mounted. Manipulators operating through bellows seals actuate moving parts by a lateral movement of fixed displacement. Thus a new piece of equipment, such as a substrate holder, is designed around the standard mount and manipulator, and can be incorporated into the system without modification of the basic structure.

A. R. Smith G. R. Heidler
G. Essler L. B. Prentice

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